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PROTECTION AND DECONTAMINATION OF LAND TARGETS AND VEHICLES

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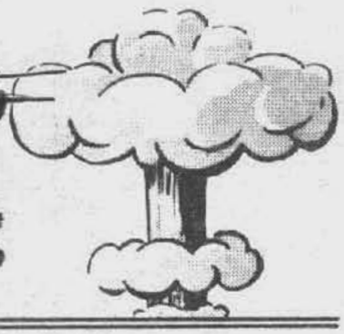

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MEMORANDUM FOR DISTRIBUTION

SUBJECT: Declassification Review of Operation BUSTER-JANGLE Test Reports

The following 100 reports concerning the atmospheric nuclear tests conducted during Operation BUSTER-JANGLE in 1951 have been declassified and cleared for open publication/public release:

WT-301 thru WT-306, WT-309 thru WT-319, WT-321 thru WT-351, WT-353, WT-354, WT-356 thru WT-370, WT-372, WT-374 thru WT-385, WT-388 thru WT-390, WT-392, WT-393, WT-396, WT-398 thru WT-402, WT-405 both volumes thru WT-407, WT-409, WT-410, WT-412, WT-415, WT-417, Wt-418, WT-422 and WT-423

An additional 12 WTs from BUSTER-JANGLE have been re-issued with deletions and are identified with an "EX" after the WT number. These reissued versions are unclassified and approved for open publication. They are:

WT-308, WT-320, WT-371, WT-373, WT-386, WT-391, WT-394, WT-395, WT-397, WT-404, WT-414 and WT-425

This memorandum supersedes the Defense Nuclear Agency, ISTS memorandum same subject dated August 22, 1995 and may be cited as the authority to declassify copies of any of the reports listed in the first paragraph above.

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Operation JANGLE

Project 6.2

PROTECTION AND DECONTAMINATION OF LAND TARGETS AND VEHICLES

by

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CHAPTER 1

INTRODUCTION

W. E. Strope

1.1 HISTORICAL BACKGROUND

From the time of the underwater atomic burst at Operation CROSSROADS, decontamination has been recognized as a complex problem not lending itself to an easy solution. However, all subsequent field tests of atomic weapons have been made under essentially non-contaminating conditions. The weapons were detonated either high in the air or atop high towers, and dispersal of the bomb clouds did not lead to a general contamination of test areas. Consequently, until Operation JANGLE, there was little opportunity for the field testing of decontamination techniques and theories on contamination-decontamination phenomenology derived from laboratory studies.

The series of experiments described in this report constitutes the first full field test of decontamination procedures. These experiments grew out of an urgent requirement for practical knowledge of decontamination procedures for military use. Although the results of these experiments are by no means definitive, they constitute a first step toward the establishment of Standing Operating Procedures for decontamination in the field.

1.2 OBJECTIVES

The specific objectives of Project 6.2 were:

1. To determine, in the field, the effectiveness of various decontamination methods in reducing the radiation fields in land areas, paved areas, buildings, and vehicles.

2. To determine, in the field, the rates, costs, and hazards of decontamination operations.

3. To study specifically those parameters of radioactive contamination that bear most heavily on the results of decontamination operations.

1.3 ORGANIZATION OF PROJECT 6.2

The various experiments in Project 6.2 were conducted by individual teams provided by the United States Naval Radiological Defense Laboratory

(USNRDL), United States Naval Civil Engineering Research and Evaluation Laboratory (USNCEREL), Engineer Research and Development Laboratories (ERDL), Chemical and Radiological Laboratory, Army Chemical Center (CRL, ACC), and the Office of the Chief of Engineers (OCE).

The test work was divided into two portions, each under a technical coordinator responsible to the Project Officer. The principal investigators in charge of each team were given complete responsibility and authority for the conduct of their team's operation under the technical coordinators. The Project Officer held nightly planning and progress conferences throughout the test period.

An organizational diagram for Project 6.2 is shown in Fig. 1.1.

1.4 FIELD OPERATIONS

The experiments reported here were conducted in November and December 1951 as part of Operation JANGLE at the Nevada Proving Grounds (NPG). Operation JANGLE consisted of two atomic weapon detonations, one on the surface (detonation time 0900, 19 November 1951) and one 17 ft below the surface (detonation time 1200, 29 November 1951). Each weapon had a yield of approximately 1.2 kt.

In late October personnel started arriving at the test site to set up experimental buildings and test areas and conduct dry runs.

Operating conditions at the test site were far from ideal. Much of the work was accomplished in snow and below-freezing temperatures. The long distances between base camp, control point, and working areas severely reduced the useful working time. A breakdown in Task Force Services shortly after the Underground Shot left a major portion of the work of Project 6.2 to be accomplished with little or no support.

Despite the adverse conditions it is felt that the objectives of the project were attained. This is a tribute to the hard work and proficiency of the project personnel.

1.5 ORGANIZATION OF REPORT

Individual chapters (2 through 11) have been written by the principal investigators on each of the ten teams indicated in Fig. 1.1. The complexity and extent of the work, which virtually dictated the organization of the teams, makes this report a symposium on the subject of contamination-decontamination rather than a tightly organized report. The sheer bulk of field data in some experiments made the inclusion of all data prohibitive. Selected data and summaries are provided wherever this applies. Complete field data for each experiment are available, and may be obtained upon application to the laboratory which conducted

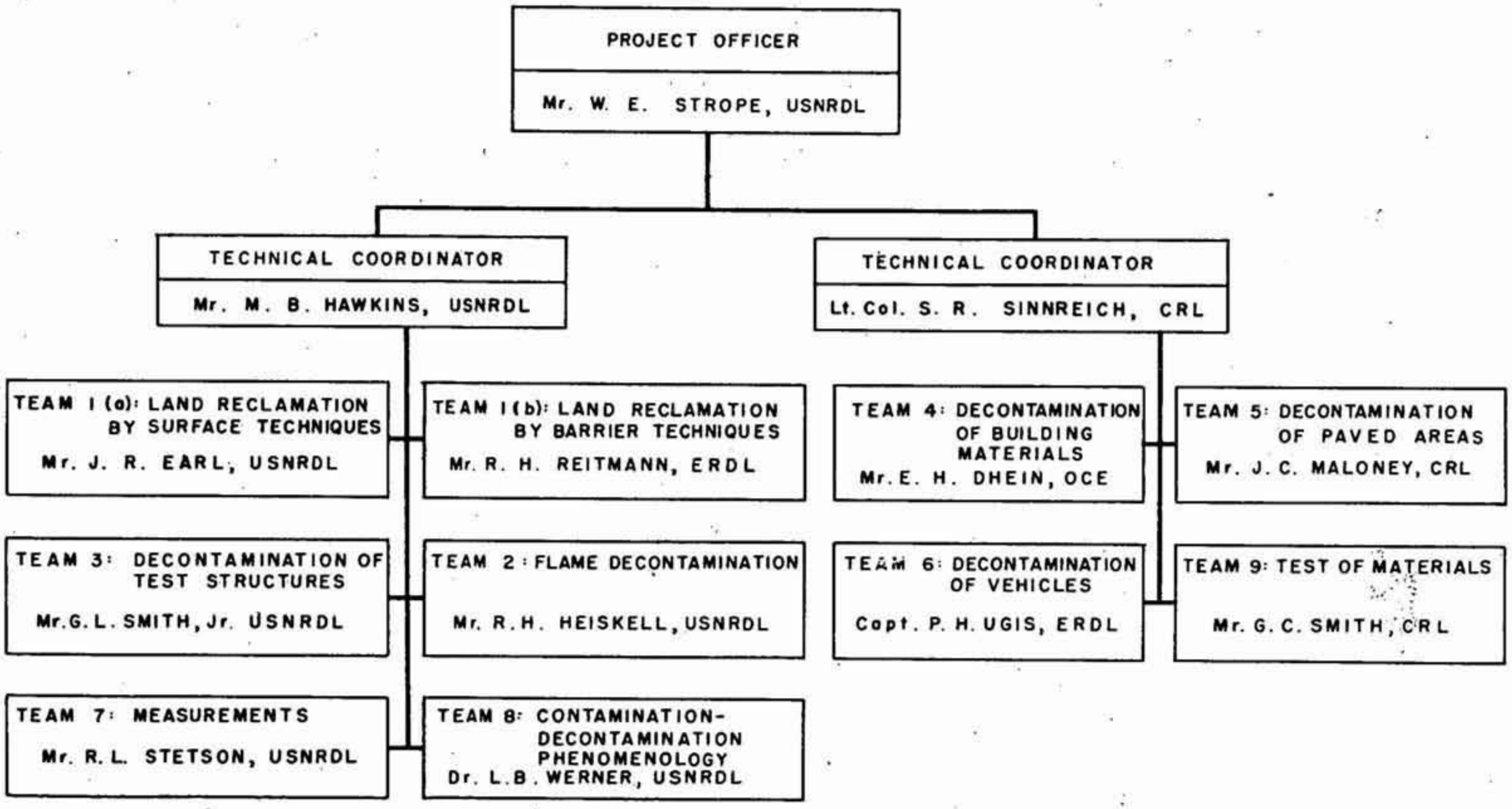


Fig. 1.1 Organization of Project 6.2

each experiment, as shown in Fig. 1.1.

Chapter 12, written by the Project Officer, summarizes the essential findings for the whole project and attempts to reconcile discrepancies in the findings of individual investigators.

1.6 ACKNOWLEDGMENTS

The Project Officer desires to acknowledge the considerable aid in the operation of Project 6.2 received from LCDR C. A. Grubb, USN, LT L. H. O'Donnell, USN, J. J. Kearns, W. Armstrong, and V. Saitta. The editorial work on this report was accomplished by A. M. Heller.

CHAPTER 2

LAND RECLAMATION BY SURFACE TECHNIQUES

J. R. Earl

2.1 ABSTRACT

Within a radioactively contaminated natural land area, the radiation field over limited sections can be substantially reduced by standard techniques of scraping, plowing, harrowing, and filling. Time, manpower, and equipment requirements do not differ significantly from those that would apply in the absence of radioactive contamination. Hazards to operating crews can be minimized readily by observance of standard radiological safety rules.

2.2 OBJECTIVES

The three main objectives of the experiments reported here can be stated generally as follows:

1. To determine the effectiveness of standard earth-moving techniques in reducing the radiation field in radioactively contaminated natural land areas.

2. To determine time, manpower, and equipment requirements for land reclamation operations.

3. To provide basic data for the evaluation of hazards to operating crews.

2.3 FIELD CONDITIONS

The tests were conducted following the Surface Shot. A general view of the experimental site is shown in Fig. 2.1. The test area was nearly plane, free of gullies or other gross surface irregularities, and covered to about 10 per cent by sagebrush from 1 to 3 ft high.

The soil was a non-compacted, noncohesive, silty sand weighing about 150 lb per cu ft. The moisture content (due primarily to rainfall before the Shot) was approximately 20 per cent to a depth of 6 in. The soil particle size distribution, determined by sieve analysis, is shown in Table 2.1.

Fig. 2.1 General View of Test Area

TABLE 2.1

Soil Sieve Analysis

Sieve Size		Per Cent Passing
Aperture (in.)	Mesh per Inch	
0.75	--	100
0.50	--	98
--	4.0	91
--	10.0	84
--	30.0	77
--	60.0	68
--	210.0	20

Wind speed varied from 5 to 15 mph and air temperature from 40 to 60 deg F. during the test.

The radioactive contaminant lay almost entirely on the surface. Rainfall after the Shot and before the tests were begun did not result in any significant penetration of the soil by the contaminant. Decay was approximately in accordance with the $t^{-1.2}$ law. The average radiation fields in which the tests were conducted (measured 3 ft above the surface), varied from 60 to 300 mr per hr, depending on the location of the individual test area.

2.4 EXPERIMENTAL PROCEDURES

Seven individual tests were conducted, each employing one or a combination of standard earth-moving techniques. Throughout this report, those techniques that involve the removal of the contaminant from the test area are called clearing methods; techniques in which the contaminant is mixed with the soil or buried under clean soil are called modifying methods.

Tables 2.2 and 2.3 provide a complete summary of the experimental procedure in each test.

2.5 RESULTS

Data on the reduction of the radiation field in each of the eight tests is summarized graphically in Figs. 2.2 through 2.5. The results of measurements of airborne hazards to operating crews are presented in Tables 2.4 and 2.5.

2.6 DISCUSSION

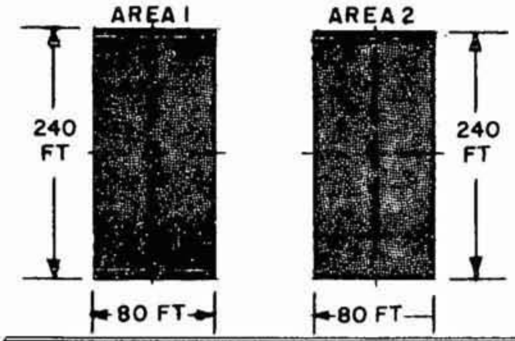
Few of the results of these tests can be generalized broadly. Conditions characteristic of the test site, combined with the experimental error normally associated with field tests, tend to make most of the results specific for the tests performed. In order to provide a realistic interpretation in the light of these limitations, performance efficiencies are stated as ranges rather than as single values.

2.6.1 Clearing Methods

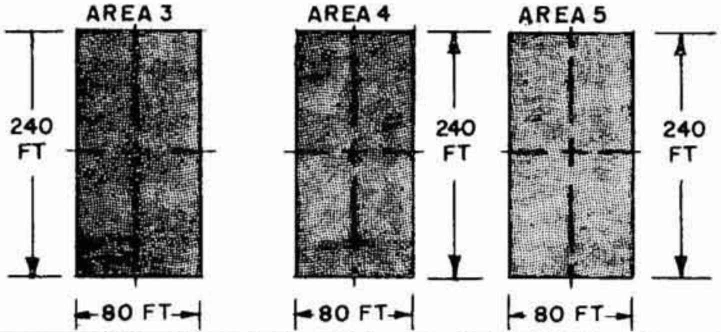
The efficiency of clearing techniques employing a motor grader or a tournapull is, roughly, 70 to 90 per cent. (See Fig. 2.2.) It was observed that all scraping operations were more efficient in

TABLE 2.2
Details of Clearing And Modifying Tests

CLEARING METHODS



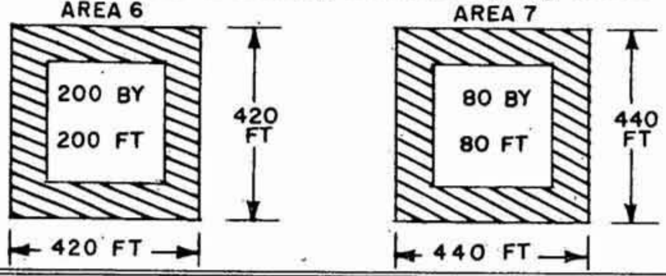
MODIFYING METHODS



Area	Operation	Equipment	Manpower	Rate (acre per hr)
1	Tournapull Scraping: 2-to-4-in. layer of soil removed from area. Spoil deposited 400 ft away from nearest edge.	12-cu-yd Le Tourneau Tournapull with a pay load of 8 cu yd. D-8 Caterpillar pusher	2	1/2
2	Motorgrader Scraping: 2-in. layer of soil scraped into side windrows along 240-ft sides.	Caterpillar self-powered motor-grader, 9-ft blade.	1	1/2
3	Plowing: Area plowed to a depth of 8 in.	3-share military-type plow, 3 ft 8 in. wide. D-8 Caterpillar to pull plow.	1	1
4	Disc-harrowing: Area disc-harrowed to a depth of 2 to 4 in.	Military-type disc-harrow, 14-in. discs, 13-ft pass. D-8 Caterpillar to pull disc-harrow.	1	1
5	Tournapull Filling: 6-in. clean soil fill placed over area. Clean fill taken from previously scraped area.	12-cu-yd Le Tourneau Tournapull with a pay load of 8 cu yd. D-8 caterpillar pusher.	2	1/8

TABLE 2.2 (Continued)

Combination Clearing And Modifying Tests



Area	Operation	Equipment	Manpower	Rate (acre per hr)
6	<u>Tournapull Scraping and Plowing</u>: 2-to-4-in. layer of soil removed from central 200-by-200-ft area. Spoil deposited 400 ft away from nearest edge. Area around 200-by-200-ft central area plowed to a depth of 8 in. and out to 420 by 420 ft.	2 12-cu-yd Le Tourneau Tournapulls with a pay load of 8 cu yd. 1 D-8 Caterpillar pusher. 2 3-share military-type plows, 3 ft 8 in. wide. 2 D-8 Caterpillars to pull plows.	2 3	1/2 Scraping 1 Plowing
7	<u>Motorgrader Scraping and Plowing</u>: 2-in. layer of soil scraped into side windrows from 80-by-80-ft area. Windrows feathered out over uncleared area. Area around central cleared area plowed to a depth of 8 in. and out to 440 by 440 ft.	2 Caterpillar self-powered motorgraders, 9-ft blade. 2 3-share military-type plows, 3 ft 8 in. wide. 2 D-8 Caterpillars to pull plows.	2 2	1/2 Scraping 1 Plowing

TABLE 2.3

Field Measurements

Measurement	Before Test	During Test	Post Test
Gamma Field	Radiation level 0, 3 and 6 ft above ground was measured within the test area at the center, corners, and ends of the major axes. Radiation level at increments of 5 ft up to an elevation of 55 ft was measured at the center of the test area.	Radiation level 0, 3 and 6 ft above ground was measured within the test area at the center and along the major axes at various distances from center.	Radiation level 0, 3 and 6 ft above ground was measured within the test area at the center, along the major axes at various distances from center and at the corners. Radiation level at increments of 5 ft up to an elevation of 55 ft was measured at the center of the test area. Radiation level 3 ft above the center of the test area was measured 24 and 48 hr after completing the tests.
Airborne Contaminant	Air samplers placed downwind, upwind, and at the center of the test area to provide a base line of normal airborne contaminant.	Air samplers placed on equipment used in test to determine amount of contaminant made airborne in vicinity of equipment operators. Air samplers placed downwind, upwind, and at the center of the test area to determine amount of contaminant made airborne by operation of equipment.	Air samplers placed downwind, upwind, and at the center of the test area to establish a post-test level of airborne contaminant. Filters from respirators worn by equipment operators were analyzed for contaminant.

TABLE 2.3 (Continued)

Field Measurements

Measurement	Before Test	During Test	Post Test
Distribution of Contaminant in Soil			Soil core samples extending through the full depth of plowed soil were taken to determine distribution of contaminant.
Exposure of Personnel to Ionizing Radiation		Exposure of personnel to ionizing radiation was indicated by use of film badges and pocket dosimeters. Shielding by equipment to operators was measured.	Film-badge and pocket-dosimeter readings were recorded.
Contamination of Equipment			Equipment used during test was surveyed to determine amount of airborne contaminant adhering to it.
Time of Operation			Elapsed time of each operation was recorded to determine rates of decontamination.

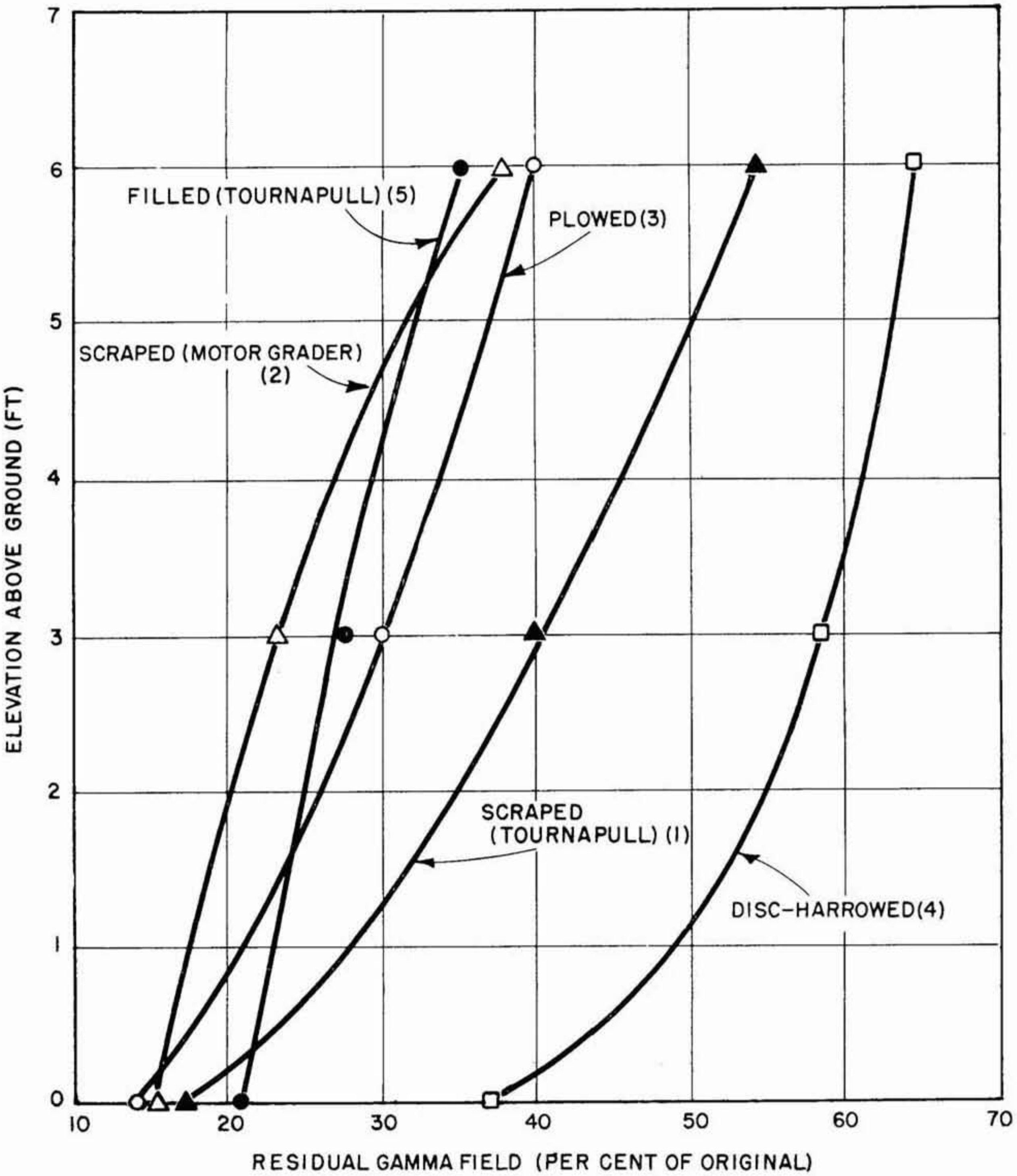


Fig. 2.2 Residual Gamma Field at Centers of Areas 1-5

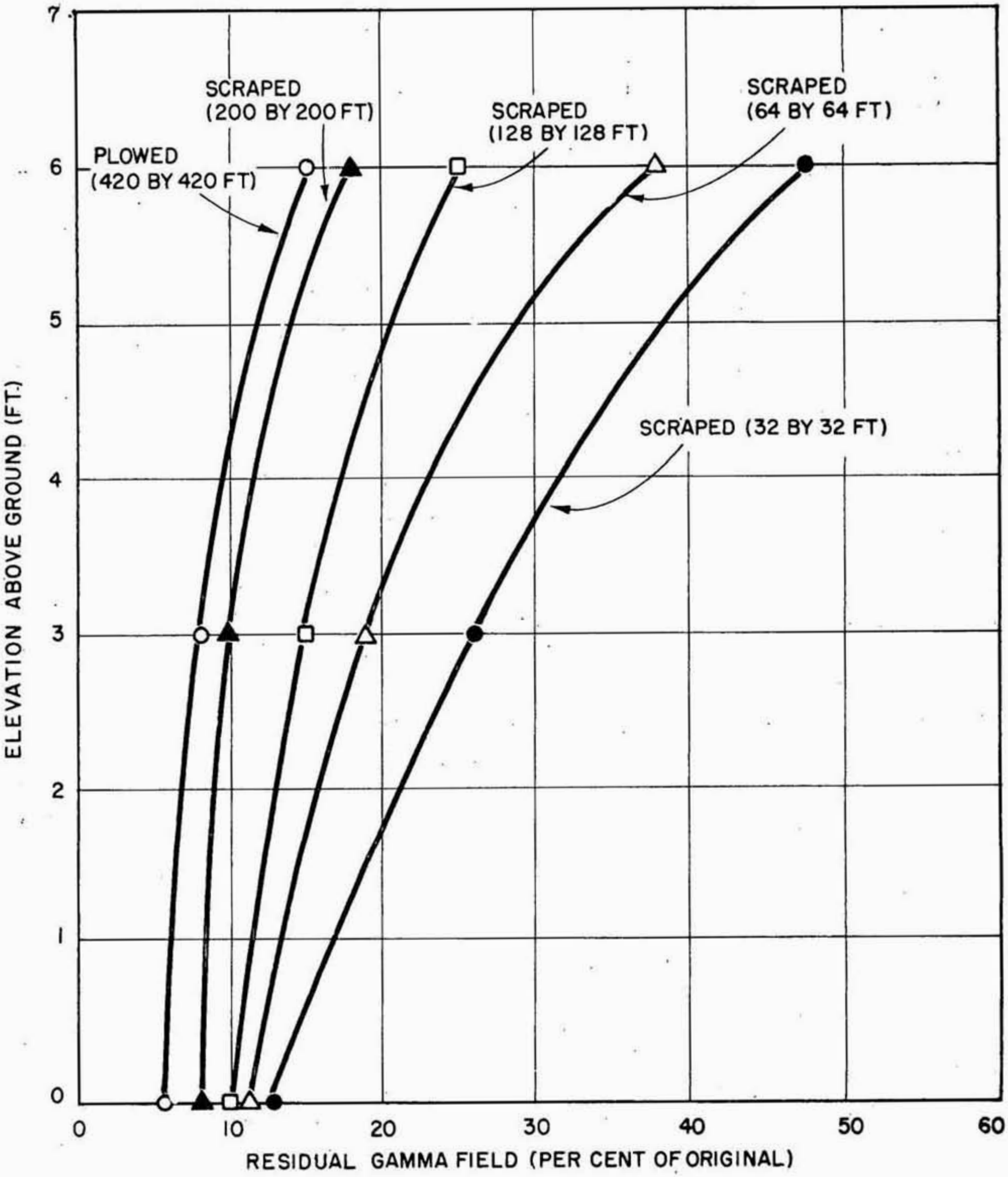


Fig. 2.3 Residual Gamma Field at Center of Area 6

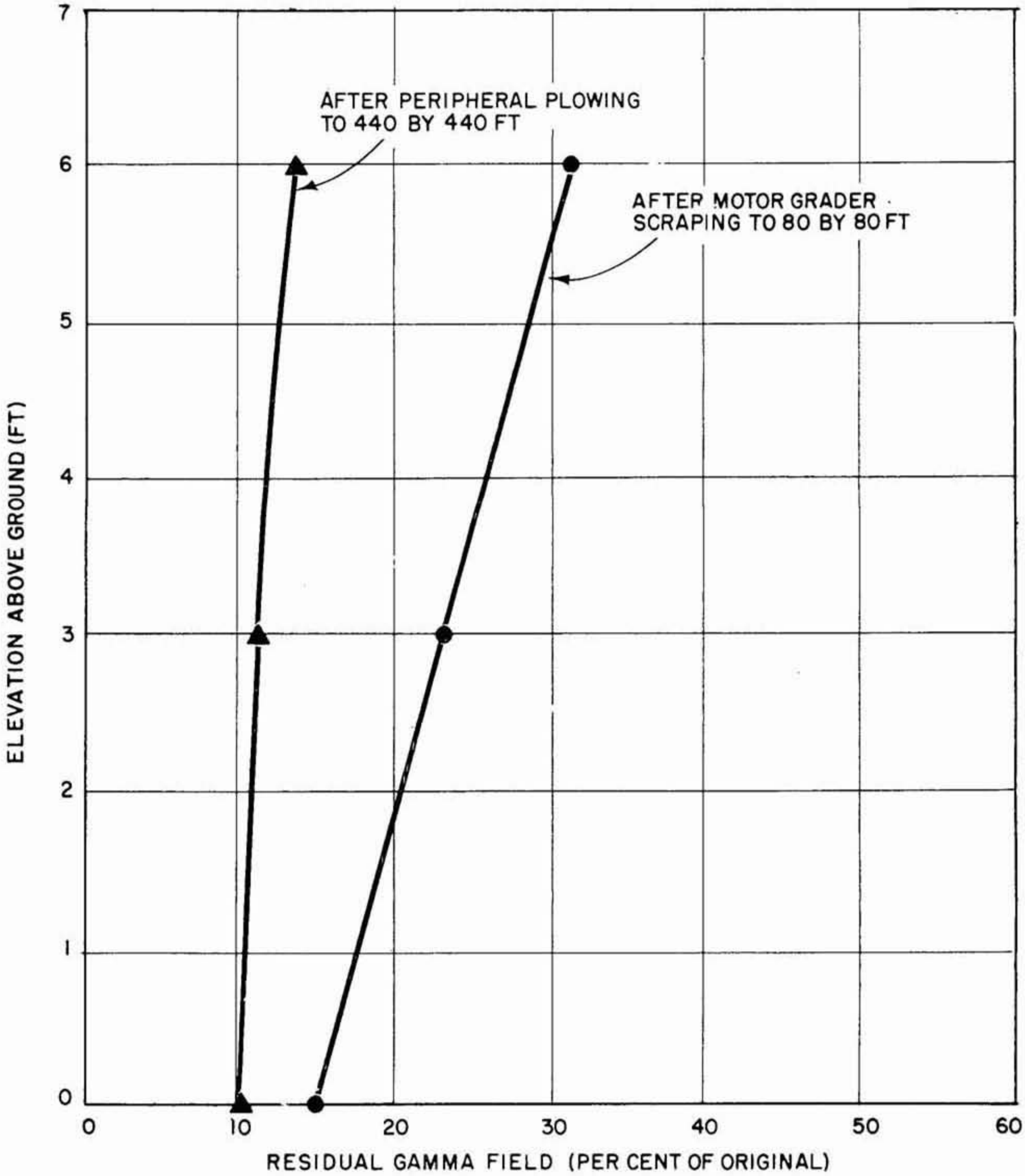


Fig. 2.4 Residual Gamma Field at Center of Area 7

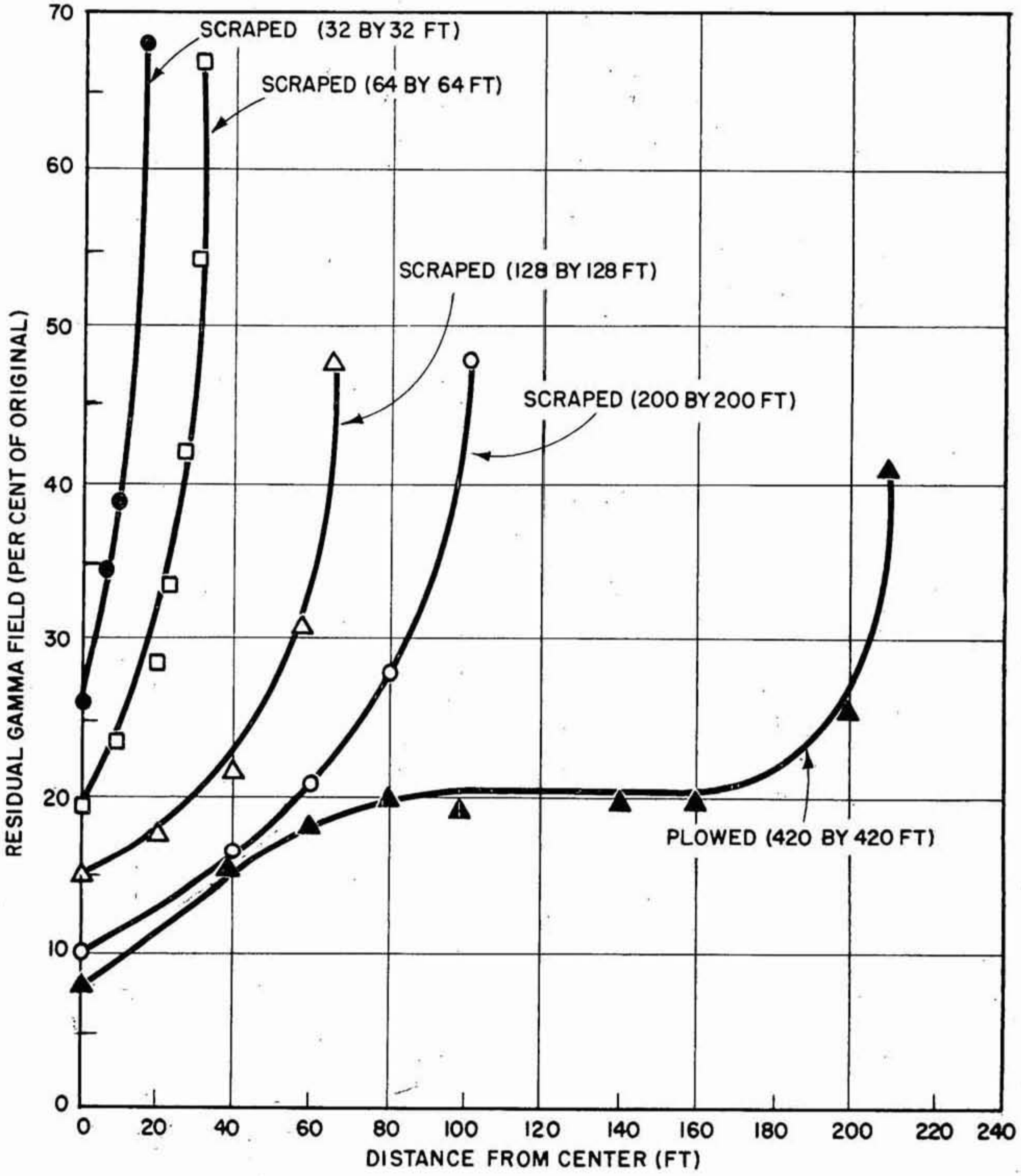


Fig. 2.5 Variation in Residual Gamma Field with Distance from Center of Area 7

TABLE 2.4

Air Sampling Data for Three Tests

Time	Area	Stationary Samplers Airborne Activity d/m/cu ft[a]				Mobile Samplers Airborne Activity d/m/cu ft[a]			
		Upwind	Center	Downwind_1	Downwind_2[b]	Plow	Cat Pusher	Tourna-pull	Motor Grader
Before Operation	1	22.0	--	71.0	--	--	--	--	--
	6	42.0	20.5	63.0	36.0	--	--	--	--
	7	9.1	17.2	17.8	--	--	--	--	--
During Operation	1	160.0	--	200.0	150.0	--	315.0	245.0	--
	6	145.0	75.0	172.0	80.0	1,200.0	2,150.0	335.0	--
	7	44.0	--	68.0	--	--	--	--	270.0
	7	--	210.0	84.0	--	5,800.0	--	--	--
After Operation	1	--	--	--	--	--	--	--	--
	6	52.0	82.0	83.0	32.0	--	--	--	--
	7	--	--	--	--	--	--	--	--

(a) Beta-gamma. Associated alpha activity was always less than 1 d/m/cu ft.

(b) Second downwind sampler located 500 ft beyond the first sampler at edge of test area.

TABLE 2.5

Activity Collected by Respirator Filters

Sample Number	Airborne Activity[a] (d/m)	
	1st Filter[b]	2nd Filter[b]
1	48,000	2,800
2	42,800	3,600
3	38,400	2,800
4	20,800	2,000
5	4,000	2,200
6	3,400	2,000
7	2,600	2,400

(a) Beta-gamma. Associated alpha was always less than 1 d/m for each filter.

(b) Respirators collected for analysis had double filters. Readings on 2nd filters would be amount of activity passing through standard respirator.

damp soil, since spillage from the ends of the cutting blades decreases as the soil becomes more cohesive. It was determined that the difference in scraping performance between the motor grader and tournapull, as seen in Fig. 2.2, was due primarily to hot spots and an abnormal amount of spillage in the tournapull test area.

The test results suggest that a thorough pre-wetting of the soil would considerably enhance the efficiency of any clearing method. However, in view of the great quantities of water required to wet a large area to a sufficient depth, it is doubtful that this can be recommended generally as a practical field procedure.

The soil removed in scraping need not be hauled any great distance for disposal. Satisfactory results may be obtained by spreading the spoil in a layer 2 to 4 in. deep just outside the area being treated.

The operational rate in scraping tests was approximately 1/2 acre per hr.

2.6.2 Modifying Methods

The effectiveness of modifying methods depends heavily on the burial pattern obtained. These methods do not remove the contaminant from the treated area, but bury or mix it on the spot. Each method produces a characteristic burial pattern, and the depth of burial for any given method can be varied by changing the depth of cut or fill. Hence, it is impossible to state a specific efficiency for any particular modifying method without a very restrictive qualification concerning the depth of burial. The following generalizations on burial depths can be made, however:

1. Filling produces uniform burial to 100 per cent of the fill.

2. In plowing, most of the contaminant is buried to a depth of 40 to 60 per cent of the depth to which the plow cuts.

3. Harrowing produces a nonuniform mixture to the depth to which the discs cut. Harrowing may, however, leave a great part of the contaminant on the surface.

The relative performances of these methods in individual tests are shown in Fig. 2.2. It is evident that the irregular mixture produced by harrowing accounts for the relatively poor performance in Area 4 (about 50-per cent reduction). Of the three modifying methods, filling and plowing are almost equally effective, and are capable of reducing a radiation field to about 10 per cent of its initial level.

2.6.3 Combinations of Clearing and Modifying Methods

Combinations of scraping and plowing were tested in Areas 6 and 7. Scraping resulted in about 20 per cent less residual radiation than plowing, and required twice as much time. Where fairly large areas are to be treated, a considerable saving in time can be effected by scraping the central portion of the area, and then plowing peripherally out to the desired distance. The net result is a large saving in operational time (and, hence, a reduction in the exposure of working crews) at the expense of a relatively small decrease in the over-all effectiveness of the operation.

This fact is illustrated in Fig. 2.6 in which two combined scraping and plowing tests are compared. The difference in the end-results of the two operations was 3 per cent in residual radiation, a barely significant figure in the light of experimental error. The difference of more than a factor of 2 in operational time is of major importance. It is evident, then, that a judicious combination of scraping and plowing can produce optimum results from the standpoints of time and effectiveness.

2.6.4 Practical Application of Test Results

Up to this point, the effectiveness of reclamation measures in reducing radiation fields has been discussed in terms of measurements taken above the center of the treated areas. As one proceeds from the center toward the edge of a treated area, however, the radiation intensity increases rather abruptly, as shown in Fig. 2.5.

If a very small area is treated, the rise in radiation intensity with distance from the center is so sharp that the benefit of the operation can be realized only at points close to the center. As the size of the area treated is increased, the radiation intensity at the center decreases by smaller and smaller amounts, as shown in Fig. 2.3. Note, however, in Fig. 2.5, that while the reduction at the center becomes less significant with increasing area, the percentage of the treated area over which a useful reduction is realized becomes significantly greater. This is evident in the change in the slope of the successive radiation gradient curves in Fig. 2.5.

For practical purposes, the necessary reduction of the radiation field must be achieved at the edge, rather than at the center of the desired working area. Figure 2.7 exemplifies the relationship between working area (i.e., usable area obtained) and treated area when scraping techniques are employed.[1]

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[1] A complete set of graphs similar to Fig. 2.7, covering all reclamation techniques both individually and in combinations, and a range of practical heights, is in preparation at USNRDL.

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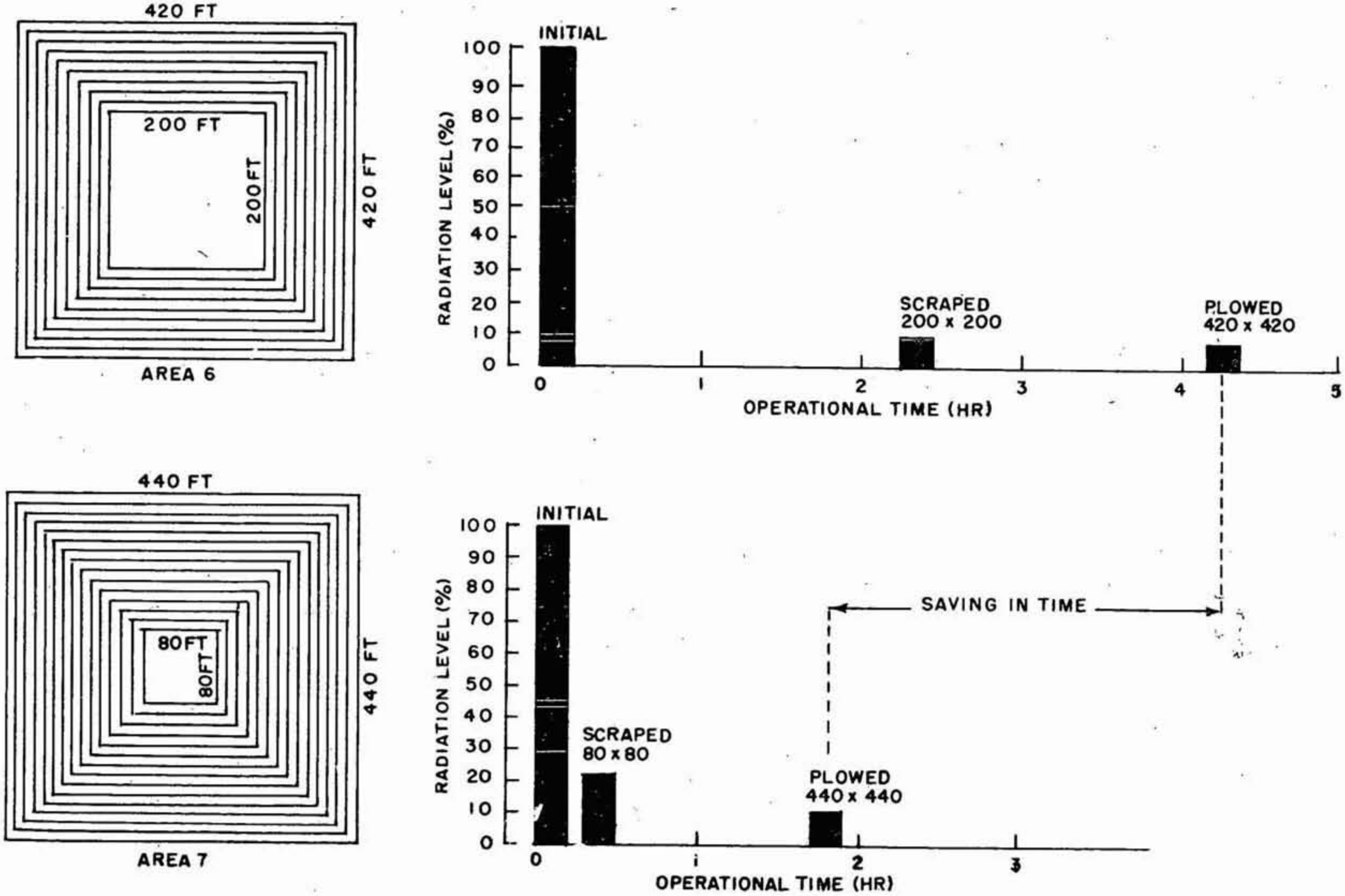

Fig. 2.6 The Time Factor in Combined Scraping and Plowing Operations

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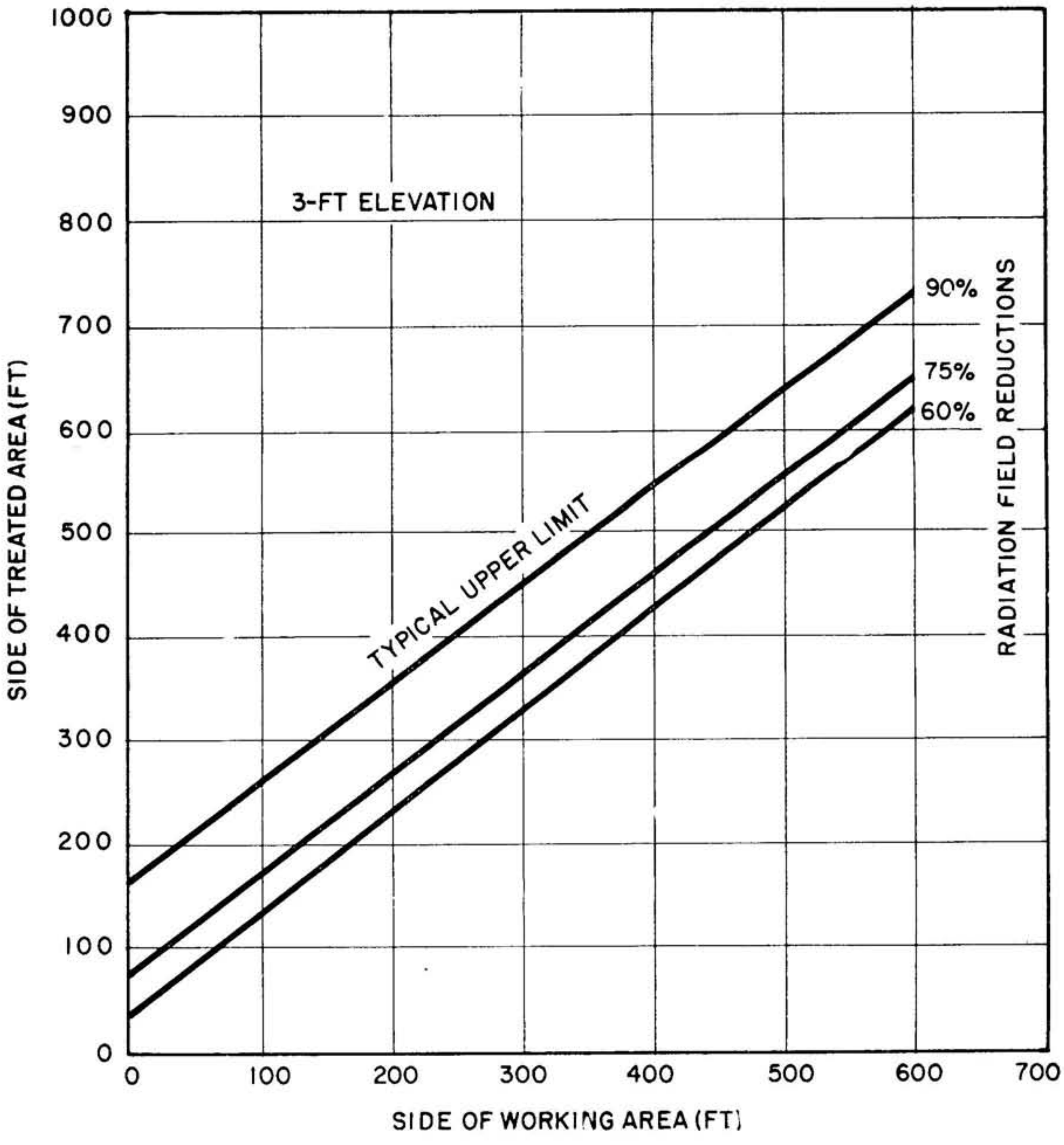


Fig. 2.7 Working Area vs Treated Area for Scraping

Example: How large an area must be scraped in order to achieve a 90-per cent reduction in the radiation field measured 3 ft above any part of a working area 300 ft on a side?

Enter Fig. 2.7 at the abscissa 300 ft. Read up to the 90-per cent line and across to the ordinate. The conditions can be met by scraping an area 450 ft on a side.

2.6.5 Hazards to Operating Crews

Film badge and quartz fiber dosimeter records kept during the operations indicated that equipment operators received about 60 per cent less exposure to ionizing radiation than they would have had they not been shielded by their equipment. It was further noted that additional reductions in anticipated dosages were afforded by the progress of the operations themselves. As a rough rule of thumb, it can be estimated that the dose received by an equipment operator during his work shift will be around 30 per cent of the dose received by a man fully exposed to the initial level in the operational area for the same length of time.

Table 2.4 shows a definite increase in the airborne activity during the operating period. It appears conclusive that an airborne hazard for equipment operators and personnel working in the immediate area does exist. It was not determined whether this hazard would exist for personnel working at some distance beyond the immediate operational area.

Standard respirators equipped with a pair of filters in series were used during the operations. It was found that in every instance, the single filter ordinarily provided in these respirators was inadequate, that the first filter passed a considerable amount of active material. Table 2.5 shows the typical results of tests made on several pairs of filters. It was noted further that activity leaked around the half-mask respirator. Half-mask respirators, in general, are inadequate for reclamation operations. A full-face mask, equipped with a Chemical Corps M-11 type canister should be provided.

2.6.6 Contamination and Decontamination of Heavy Equipment

The level of contamination picked up by heavy equipment used during these tests rarely exceeded 10 per cent of the level of the radiation fields in which the equipment was operated. Decontamination of the exterior surfaces was accomplished satisfactorily with high-pressure hoses. The interiors of closed cabs were contaminated almost as heavily as exterior surfaces, but responded satisfactorily to decontamination with vacuum cleaners.

It was observed that operations in wet soil led to somewhat higher levels of equipment contamination, as wet soil clung more readily than dry to tires, tractor treads, and other under surfaces. However, high-pressure hosing served adequately for decontamination under these circumstances.

2.6.7 Recontamination of Reclaimed Areas

Gamma measurements made in each test area 24 hr after the completion of each test did not reveal any significant recontamination. It is possible, however, that the dampness of the soil after the Surface Shot and the relatively large particle size produced tended to prevent redistribution of the contaminant by the wind. A considerable amount of redistribution was noted after the Underground Shot when the soil was dry, and the particle size small. Currently available data is inadequate for a thorough evaluation of the recontamination problem.

2.6.8 Manpower, Equipment, and Time

It should be understood that the manpower, equipment, and time relationships shown in Table 2.2 are fairly specific for these tests. Such factors as soil type, topography, condition of haul roads, and hauling distances may grossly affect operational rates. However, since the radiological problem has virtually no effect on operational rates, and since standard equipment and techniques are used, any competent field engineer should be able to estimate rates, given a knowledge of the field conditions.

2.6.9 Miscellaneous Observations

It was found that although the contaminant lay almost wholly on the surface, the radiation fields above the test areas corresponded closely to fields that would be produced by contaminants mixed with the top layer of soil. This phenomenon can be attributed to shielding effects produced by surface roughness. For the conditions of these experiments, it was found that the surface roughness could be expressed in terms of an equivalent depth of mixture of 1/2 in. A correction for surface roughness should be introduced in any attempt to predict the results of land reclamation efforts theoretically, if any fair degree of accuracy is desired.

It was found that in areas within 3,000 ft of the bomb crater, the radiation field was due, in large part, to contamination in the crater and on the crater lip. It is, therefore, advisable to determine, before any land reclamation effort is made, that the area to be treated lies beyond the effective reach of "crater shine".

2.7 CONCLUSIONS

1. Radiation fields within contaminated natural land areas can be reduced 70 to 90 per cent through the use of standard earth-moving procedures and equipment.

2. Manpower requirements and operational rates do not vary significantly from those that would apply in the absence of radioactive materials.

3. In scraping operations, it is unnecessary to haul the spoil any further than the boundaries of the area to be treated. This material should be spread in a layer 2 to 4 in. deep.

4. Due to the shielding afforded by equipment, the radiation dosage received by equipment operators will be from 60 to 70 per cent less than the dosage received by unshielded personnel working in the same area for the same time.

5. Internal hazards due to the presence of airborne activity during operations can be minimized by the use of standard protective clothing and full-face respirators.

6. Recontamination of treated areas through wind action is relatively unpredictable on the basis of present knowledge.

7. Contamination of operating equipment does not constitute a serious hazard. In general, equipment will pick up a maximum of 10 per cent of the level of the field in which it operates. Decontamination to acceptable tolerance levels can be accomplished adequately with high-pressure hoses.

2.8 RECOMMENDATIONS

In view of the particular limitations of the tests reported here, the conclusions drawn should be used only to provide broad planning outlines. Further tests in which variations due to soil conditions, topography, and type of contaminating event can be determined should be attempted.

It is feasible, nevertheless, to write a standing operating procedure for land reclamation on the basis of the tests reported here. This standing operating procedure could serve until such time as further tests provide the necessary material for revision and augmentation.

CHAPTER 3

LAND RECLAMATION BY BARRIER TECHNIQUES

R. H. Reitmann

3.1 ABSTRACT

A series of four experiments were conducted after the Surface Shot in an effort to evaluate the protection afforded to personnel traversing or occupying a radioactively contaminated region by interposing earth barriers between the radiation source and the area of occupancy.

The relative protective merits of a foxhole, a continuous trench, a sunken roadway, and a circular cleared area within a contaminated region were evaluated in terms of the reduction in dosage afforded to personnel occupying them. Barrier techniques were compared to surface techniques (Chapter 2) in terms of radiation reduction, working area, and effort required.

It was found that an earth wall 4.5 ft high on either side of a roadway reduced the radiation field in the roadway by a factor of about 3.5.

The radiation intensity at the bottom of a foxhole and a trench was found to be less than that at 3 ft above the ground by a factor of about 20.

A circular cleared area 180 ft in diameter afforded a radiation reduction of a factor of 5, measured 3 ft above the center. It was determined that increases in the diameter of the clearing beyond 200 ft did not afford any significantly greater reduction at the center.

In comparing barrier and surface techniques, it was found that for a given amount of time, and using identical equipment, surface clearing yielded a greater maximum reduction in the radiation field (by a factor of 1.5) and produced approximately 4 times the working area (see Sec. 2.6.4) produced by the barrier technique.

3.2 OBJECTIVES

The experiments reported here had the following general objectives:

1. To measure the reduction of radiation intensity in areas protected by earth barriers within radioactively contaminated regions.

2. To compare surface techniques (Chapter 2) and barrier techniques in terms of effectiveness and effort required.

3. To investigate recontamination of cleared areas within the barrier system due to air migration of contaminants.

4. To determine the effects of radiological hazards on the production rates of engineer equipment used in these experiments.

3.3 PROCEDURE

The four tests were conducted in Areas 1 and 2, as indicated in Fig. 3.1.

The 30-by-100-ft roadways were constructed with two D-7 angledozers. The roadbeds were deepened in successive passes, and the spoil windrowed along the edges to form the barriers. The ends of the roadways were walled in to simulate roads of infinite length. Radiation intensity readings at 0, 3, and 7-ft elevations were taken at the points indicated in Fig. 3.1 for barrier heights of 0, 3, and 4.5 ft.

The circular clearing (180-ft diameter) was made in three successive operations with a bulldozer, pushing the top 2 in. of soil toward the perimeter. The circle was cleared to 60-ft diameter, then to 120-ft, and finally, to 180-ft. Intensity readings were taken 3 ft above the ground at the center, and at 30-ft intervals along the north-south and east-west diameters after each clearing operation, as shown in Fig. 3.1.

The foxhole (1.5 ft wide, 6 ft long, and 4 ft deep) and the two mutually perpendicular trenches (each 1.5 ft wide, 40 ft long, and 4 ft deep) were dug with a Barber-Greene vertical ditcher. The major axes of the foxhole and the trenches were oriented as shown in Fig. 3.1, which also indicates the points at which intensity readings were made at elevations of 0 (on the bottom), 3, and 7 ft.

Additional intensity readings were made at selected reference points outside each working area. These readings provided a check on the instruments as well as a standard with which to compare day-to-day decay.

For all readings on or above the surface, the operator faced due south, holding the meter (AN/PDR-T1B) horizontally before him with the meter face up, thus providing a constant meter orientation throughout.

3.4 RESULTS AND DISCUSSION

3.4.1 Roadway Tests

The major results of the roadway tests are shown graphically in Fig. 3.2. The result in Area 1, an average of 44 per cent residual

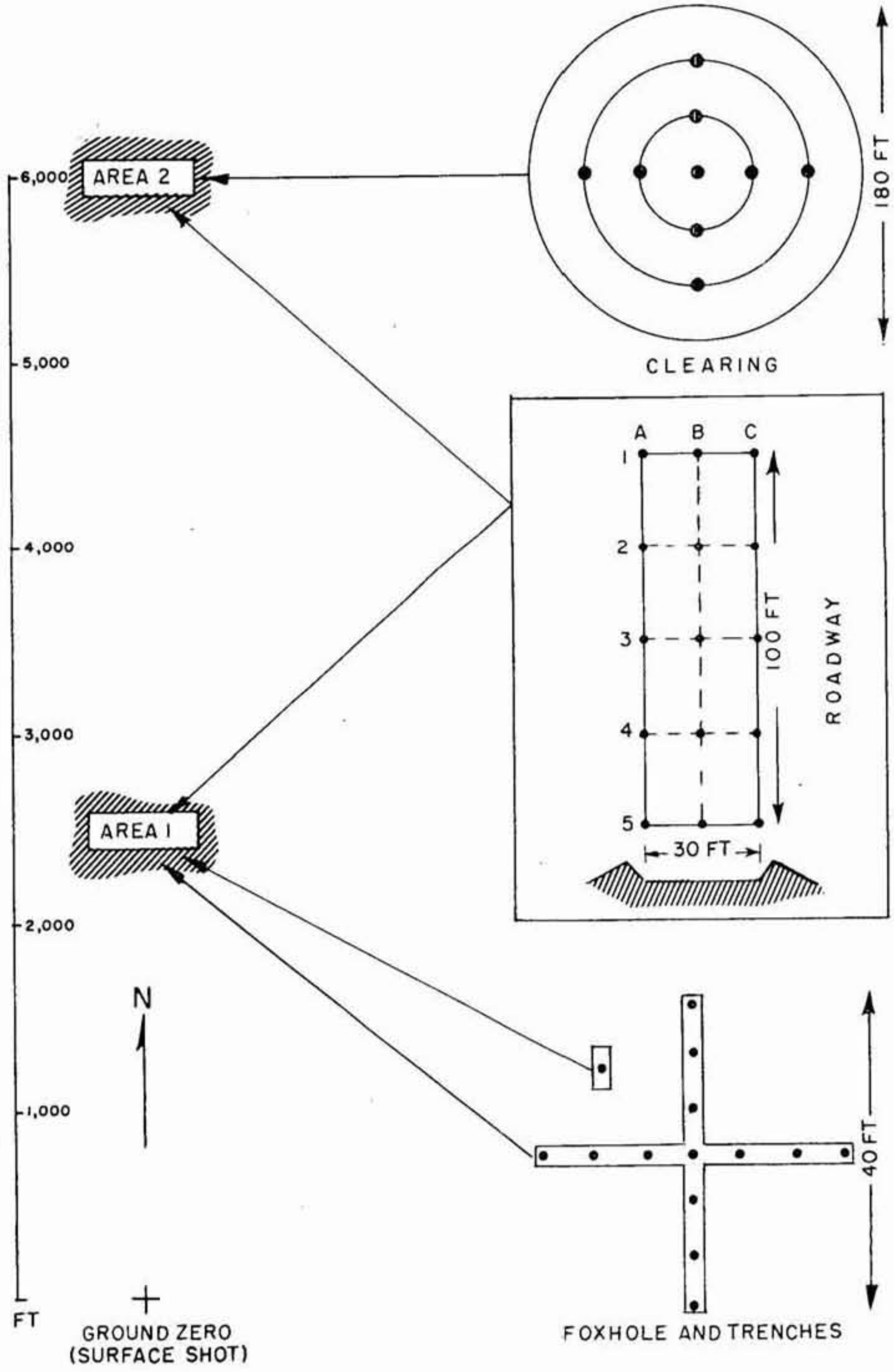
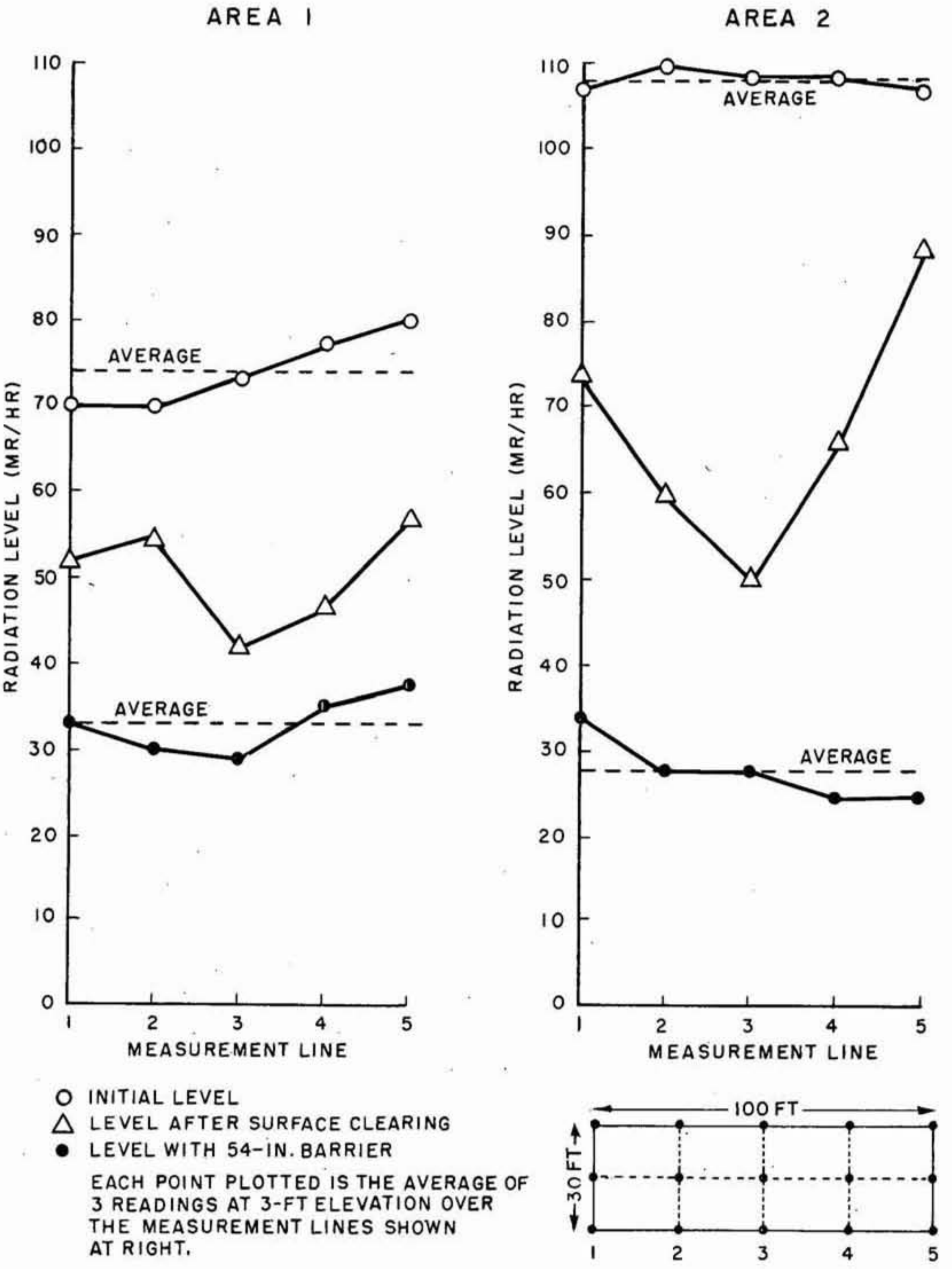


Fig. 3.1 Layout of Test Areas



EACH POINT PLOTTED IS THE AVERAGE OF 3 READINGS AT 3-FT ELEVATION OVER THE MEASUREMENT LINES SHOWN AT RIGHT.

Fig. 3.2 Results of Roadway Tests

radiation (at 3 ft) for a barrier height of 4.5 ft, was poorer than anticipated. It was determined, by additional measurements, that scattered gammas from a heavily contaminated region immediately to the west of Area 1 contributed largely to this result.[1]

Area 2 was located in a fairly uniformly contaminated region having a higher average initial intensity than Area 1. In Area 2, the average residual radiation, 3 ft over the road, was 26 per cent of the initial level for a barrier height of 4.5 ft.

It was determined, in Area 1, that barriers higher than 4.5 ft did not afford sufficient additional reductions to warrant the effort required to erect them. Unfortunately, this conclusion could not be tested in Area 2, where a layer of caliche at a depth of 18 in. prevented further deepening of the roadbed and raising of the barrier beyond 4.5 ft. The pertinent data are plotted in Fig. 3.3.

3.4.2 Circular Cleared Area

The step-by-step results obtained in clearing the circular area are shown in Fig. 3.4. It was noted that increasing the diameter of the clearing beyond 200 ft did not afford significant additional reductions at the center of the clearing. It is important to note, however, that as the area of the clearing is increased, even beyond 200 ft, the portion of the area over which a considerable general reduction is obtained increases significantly.

The circular area was cleared in the same time it took to erect 4.5-ft barriers on either side of 30-by-100-ft roadways. For a proper comparison of the effectiveness of two techniques, the working areas produced by each must be compared.

For the road in Area 2, the 4.5-ft barrier reduced the radiation field to 26 per cent of its initial level, and this reduction was fairly constant over the entire area between the barriers. As seen in Fig. 3.4, the maximum reduction, at the center of the circular area, brought the field to 19.5 per cent of its initial level. The portion of the circular area over which a reduction of 19.5 to 26 per cent was obtained was roughly 120 ft in diameter. Hence, for the same expenditure of time and effort, the barrier technique produced a working area of 3,000 sq ft as compared to roughly 11,000 sq ft for the surface clearing technique. The

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[1] There was no indication that crater shine influenced the result, despite the proximity of Area 1 to the crater.

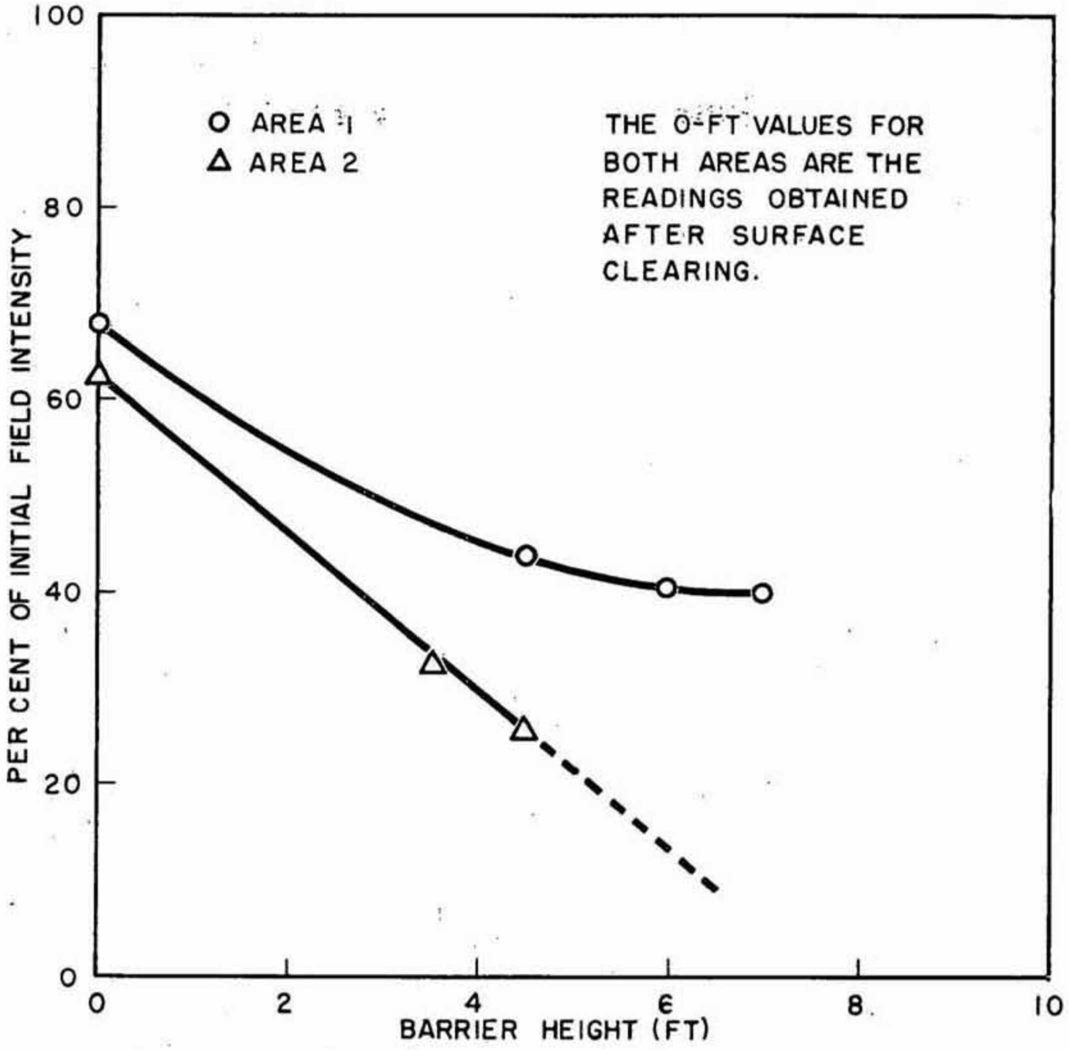


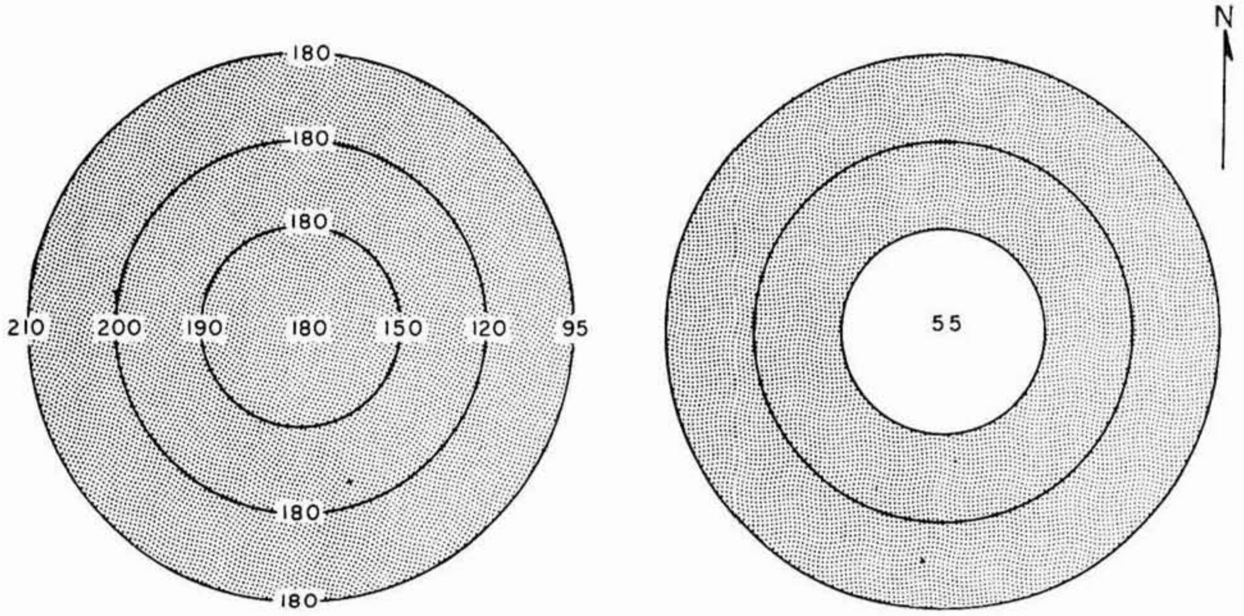
Fig. 3.3 Effect of Barrier Height on Field Intensity

surface clearing technique, then, is more effective than the barrier technique in both the maximum reduction afforded and the working area produced.

3.4.3 Foxhole and Trenches

The average field intensity 3 ft above the foxhole site was 70 mr/hr. Immediately after excavation, the field intensity at the bottom of the foxhole was 3 mr/hr, and the average intensity at points 1 ft below the edge of the hole was 12 mr/hr.

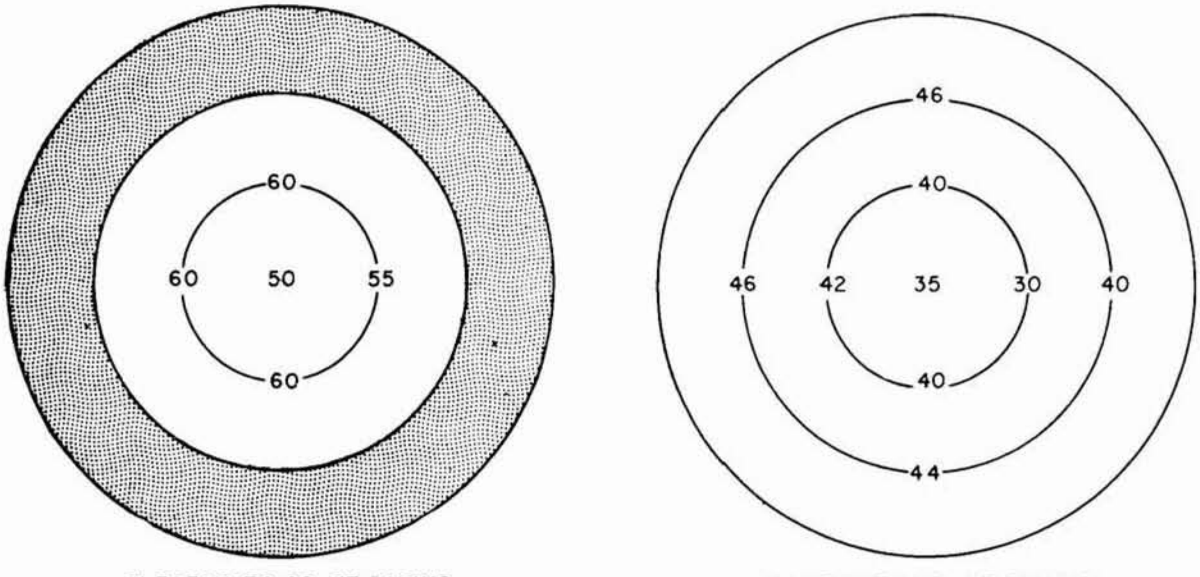
The average field intensity in the neighborhood of the trenches was 80 mr/hr. The intensity at the bottom of the trenches averaged 3 mr/hr, and the intensity at points 1 ft below the edges averaged 12 mr/hr. The difference in orientation of the two trenches had no noticeable effect on the results.



INITIAL READINGS
(MR/HR)

CLEARED TO 30-FT RADIUS
(30.5 PER CENT OF INITIAL
AT CENTER)

SCALE: = 60 FT



CLEARED TO 60-FT RADIUS
(28.0 PER CENT OF INITIAL
AT CENTER)

CLEARED TO 90-FT RADIUS
(19.5 PER CENT OF INITIAL
AT CENTER)

Fig. 3.4 Reduction of Radiation Field in Circular Cleared Area

3.4.4 Recontamination Study

There was, in general, no great amount of recontamination in either of the two test areas. It is probable that the rain and snow, on the second and fourth days after the Surface Shot, stabilized the test site sufficiently to prevent extensive air migration of the contaminant.

3.4.5 Radiological Hazards and Operational Rates

In all of the tests conducted, the operational rates for the engineer equipment used were unaffected by the presence of radioactive contaminants. All operating personnel wore respirators and protective clothing without impairing their efficiency. None of the equipment became contaminated to a level that would present a hazard to either operators or maintenance personnel.

3.5 CONCLUSIONS

1. An earth wall 4.5 ft high on either side of a road in a contaminated area was capable of reducing the radiation field over the road by a factor of about 3.5.

2. Surface clearing was more effective than the barrier technique, producing a greater maximum reduction in the radiation field (by a factor of 1.5 for the test conditions) and a greater working area (4 times greater for the test conditions) for the same expenditure of time and effort.

3. Personnel on the bottoms of trenches or foxholes 4 ft deep would have received, roughly, 1/20 of the dosage they would have received if fully exposed on the surface in the same area.

4. Radiological hazards to personnel were minimized through the use of respirators and protective clothing.

5. The operational rates of engineer equipment were unaffected by the presence of radioactive contaminants. The level of contamination picked up by this equipment during operations did not constitute a hazard to either operators or maintenance personnel when proper precautions were exercised.

CHAPTER 4

FLAME DECONTAMINATION

R. H. Heiskell

4.1 ABSTRACT

A flame decontaminating unit (USNRDL Flaminator) incorporating a burner, a surface removal tool, and a vacuum pickup system was tested on wood, asphalt, and concrete surfaces contaminated by the Underground Shot. The decontamination efficiency of this unit was checked against the efficiency of conventional surface removal, sweeping, and vacuuming techniques not employing flame treatment. It was found that flame treatment increased the efficiency of surface removal techniques on wood and concrete by 25 to 95 per cent. Flame softening of asphalt followed by scraping removed 97 per cent or more of the contaminant. Performance data on the Flaminator indicated that the unit is operationally feasible at full scale.

4.2 OBJECTIVES

The experiments reported here had the following objectives:

1. To test the decontamination efficiency of flame treatment.
2. To compare the relative merits of the Flaminator with sweeping, vacuuming, and various surface removal techniques for wood, concrete, and asphalt surfaces.
3. To provide basic data for the evaluation of radiological hazards associated with flame cleaning operations.

4.3 EXPERIMENTAL PROCEDURE

Figure 4.1 is a general plan of the test areas showing their location with respect to ground zero of the Surface Shot and the gross details of the layout within each area.

A description of the main features of the wood, asphalt, and concrete surfaces is given in the following sections:

4.3.1 Wood

The wood test strip was assembled from wood sections

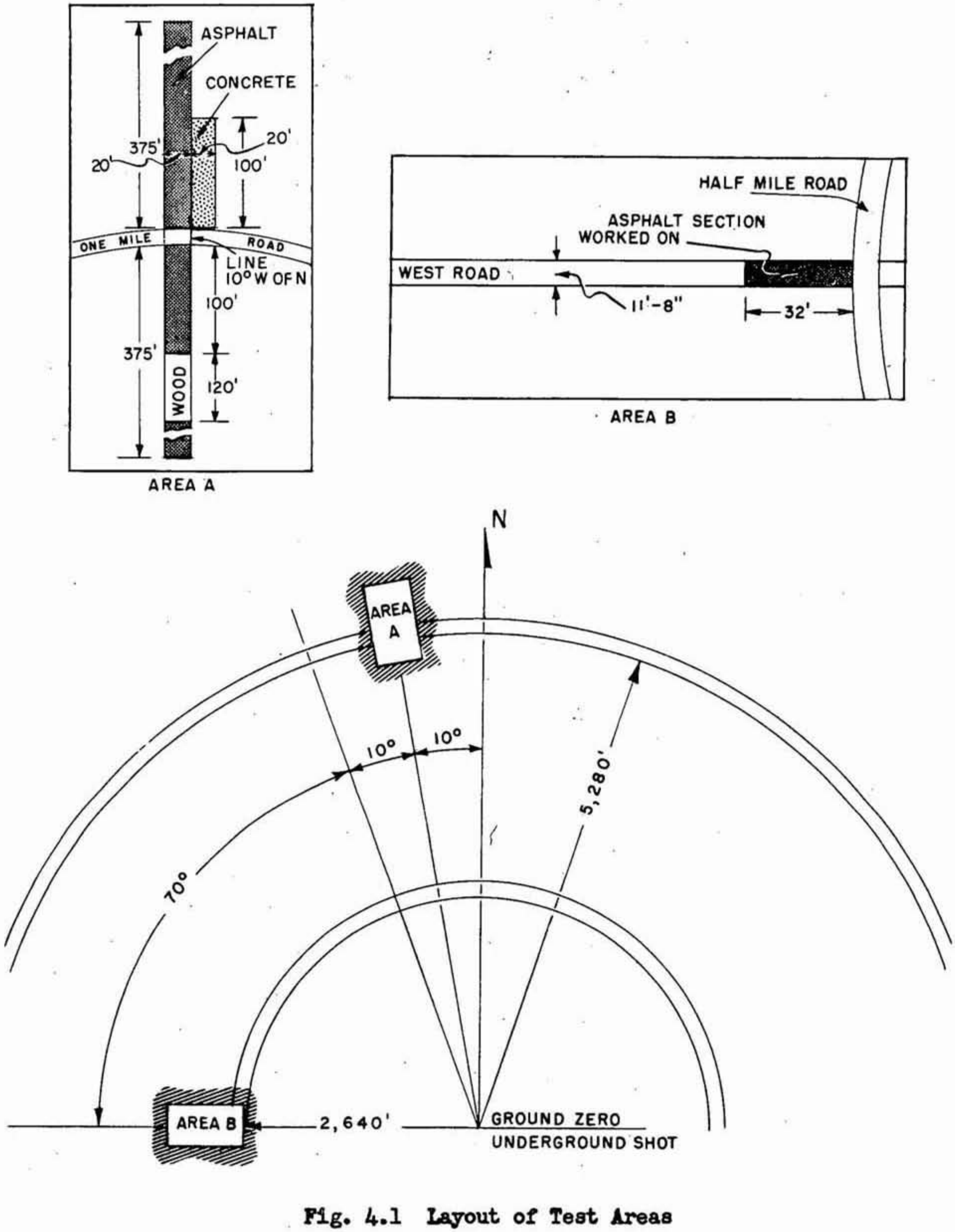


Fig. 4.1 Layout of Test Areas

prefabricated at USNRDL. These sections consisted of three varieties of unpainted wood (fir, teak, and pine) which might be found on a ship's deck. No paying or calking material was used in the cracks between the boards. The wood strips were arranged to permit determination of the relative efficiencies of with-grain vs cross-grain operation.

Flat-head nails were countersunk into the wood strips for beta-measurement reference points and for use in determining the amount of surface removed by each wood decontamination procedure. Two nails were located in every 5-ft section along the center line of each run, which gave eight measurements per run or four for each 10-ft section of with-grain or cross-grain travel.

4.3.2 Asphalt

The asphalt test strip consisted of abnormally large surface aggregate, and was not typical of the type of asphalt found on well-surfaced highways or runways. (The aggregate in the asphalt ranged from 1 to 3 in. instead of the normal pea-gravel usually used in a good grade of asphalt.)

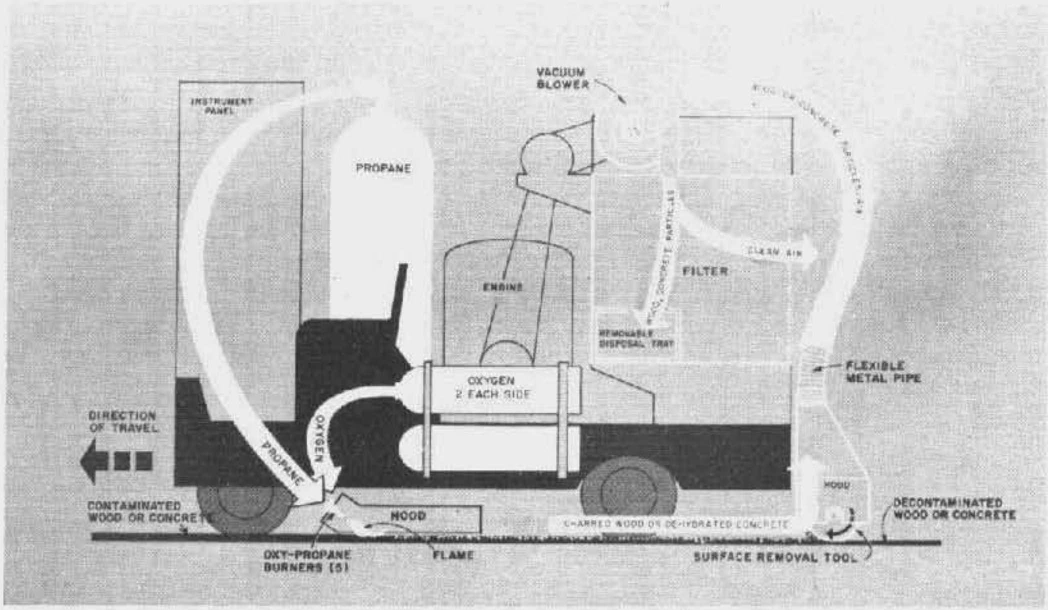
The asphalt roadway shown in Fig. 4.1 was marked off into a strip 32 ft long and 11 ft 8 in. wide. The area was further subdivided into 5 strips or runs 28 in. wide. Radiation measuring points were marked off every 4 ft along center lines of each 28-in. strip. Beta measurements were made with the USNRDL beta probe on the surface at each of these points. The test strips were first decontaminated by the Flaminator fitted with the fiber brush, and then the same area was further decontaminated by the burner and scraper.

4.3.3 Concrete

The concrete test strip had a very rough finish which would represent one of the most difficult surfaces to decontaminate. The concrete strip was divided into two 32-ft sections, one of which was used after the surface detonation and one of which was reserved for decontamination studies after the Underground Shot. Each of these test areas was divided into test strips 28 in. wide and reference points were marked with a center punch every 4 ft along the center line of each strip. Beta probe measurements were made at each one of these points before and after each pass.

4.3.4 Flaminator and Equipment

The Flaminator is shown in Fig. 4.2.



Operational Diagram (Wood or Concrete)
FLAMINATOR

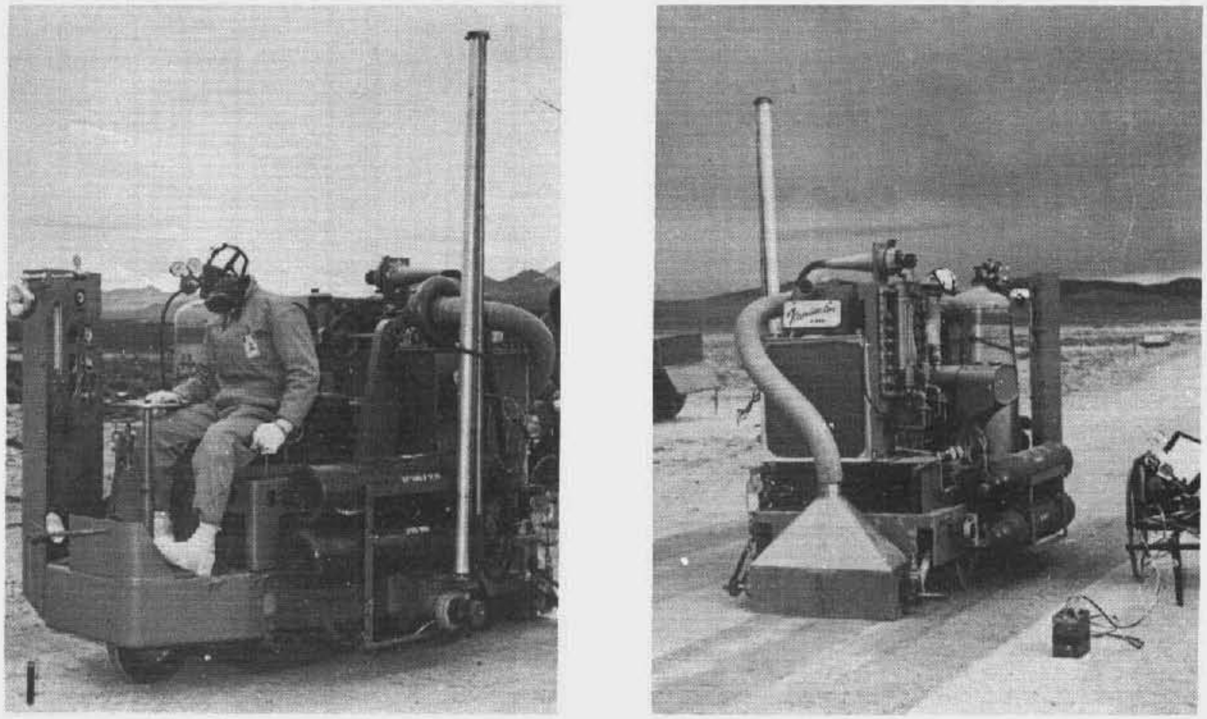


Fig. 4.2 USNRDL Flaminator

Accessories to the Flaminator included:

For wood: fiber brush, wire brush, Revo tool, and sander.

For asphalt: fiber brush and scraper.

For concrete: fiber brush, wire brush (solid fill, knot, and Tennant types), and Revo tool.

4.3.5 Additional Procedures

In conjunction with the decontamination runs, studies were made of costs and performance rates and of amounts of waste resulting from each operation.

During decontamination operations the amount of contamination in the burner exhaust gases and in the atmosphere surrounding the surfaces was determined by Team Number 7. The equipment used to obtain the samples for those determinations was designed by this group. A cap placed over the 3-in. burner exhaust line covered approximately one-third of the opening. To this cap, an electric blower was connected by appropriate fittings which drew a portion of the exhaust gases through approximately 27 sq in. of a special filter medium. Another filter of this size was located approximately 6 in. away from and in the center of the exhaust side of the U. S. Army Chemical Corps M-6 filter.

To sample the contamination in the surrounding air, an air sampler was placed near each of the test strips during the decontamination operations.

4.4 RESULTS

The results of these tests, presented as tables on the following pages, consist of representative samples of data taken from the complete field data sheets available at USNRDL.

Tables 4.1 through 4.3 present the results of the decontamination operations on the wood, asphalt, and concrete surfaces.

Table 4.4 covers the air sampling data.

Table 4.5 presents the data on contaminated wastes collected during operations.

Operational rate and cost figures are given in Table 4.6.

TABLE 4.1

Wood Decontamination Results

Flaminator Accessory	Type of Wood	Contaminant Level[a]				Total Surface Removed (in.)			
		Without Burner		With Burner		Without Burner		With Burner	
		With Grain	Cross Grain	With Grain	Cross Grain	With Grain	Cross Grain	With Grain	Cross Grain
Wire Brush	Fir	3,900	6,700	20,000	24,000				
		15.8	65.1	21.0	22.2	-	0.003	0.006	0.018
		11.3	48.7	2.8	8.5	0.010	0.021	0.028	0.048
	Teak	5,000	6,020	18,200	23,800				
		23.2	31.2	15.5	28.9	0.001	0.001	0.008	0.012
		9.2	10.6	1.5	12.0	0.012	0.015	0.029	0.047
	Pine	6,120	9,480	20,600	25,000				
		55.2	61.4	29.4	9.3	-	0.017	0.009	0.024
		9.8	44.7	15.0	1.7	-	0.029	0.035	0.054
Revo Tool	Fir	5,860	9,360	6,300	7,800				
		74.4	76.9	21.6	26.7	0.034	0.000	0.025	0.018
		30.8	33.1	7.6	7.9	0.068	0.059	-	-
	Teak	8,300	10,500	8,000	11,400				
		48.2	44.8	27.8	19.3	0.013	0.002	0.007	0.004
		14.2	16.4	1.8	3.3	0.020	0.034	0.052	-
	Pine	7,960	8,860	8,700	8,700				
		56.5	35.8	31.7	7.6	0.005	0.023	0.009	0.033
		13.6	7.4	6.9	2.8	0.026	0.047	0.037	0.111
	Fir	7,200	7,560	7,200	8,060				
		68.9	45.8	19.7	30.5	0.017	0.004	0.010	0.011
		28.2	33.9	16.5	25.2	0.036	0.021	0.039	0.053
Sander	Teak	8,000	8,400	7,000	8,400				
		47.5	31.1	10.3	18.6	0.006	0.008	0.012	0.014
		11.3	7.5	7.4	14.0	0.021	0.028	0.040	0.049
	Pine	7,100	7,060	6,100	7,500				
		38.0	9.6	11.1	4.5	0.009	0.010	0.020	0.067
		9.9	5.7	4.6	2.2	0.027	0.027	0.060	0.103

[redacted]

TABLE 4.1 (Continued)

Wood Decontamination Results

Flaminator Accessory	Type of Wood	Contaminant Level(a)				Total Surface Removed (in.)			
		Without Burner		With Burner		Without Burner		With Burner	
		With Grain	Cross Grain	With Grain	Cross Grain	With Grain	Cross Grain	With Grain	Cross Grain
Fiber Brush	Fir	7,600	14,000	-	-	-	-	-	-
		61.0	51.0	-	-	-	-	-	-
		53.0	48.0	-	-	-	-	-	-
	Teak	12,200	20,600	-	-	-	-	-	-
		46.0	33.0	-	-	-	-	-	-
		39.0	28.0	-	-	-	-	-	-
	Pine	10,600	15,800	-	-	-	-	-	-
		53.0	73.0	-	-	-	-	-	-
		47.0	54.0	-	-	-	-	-	-

(a) The first figure listed for each type of wood is the initial beta level (mμc). The second and third figures are the residual beta levels after the first and third passes respectively.

TABLE 4.2

Asphalt Decontamination Results

Run Number	Initial Level (mμc)(a)	Brushing and Vacuuming (mμc)	Per Cent Residual	Level after Burning and Scraping (mμc)	Per Cent Residual (Based on Initial Level)(b)
1	5,560	1,480	26.6	340	6.1
2	6,460	1,700	26.3	160	1.4
3	6,100	2,150	35.2	260	4.3
4	4,860	2,800	57.6	140	2.9
5	4,880	2,012	41.2	84	1.7

(a) Beta measurement. Window area approximately 100 sq cm.

(b) These values would be the same for burning and scraping without prior vacuuming and brushing.

TABLE 4.3

Concrete Decontamination Results

Flaminator Accessory	Time (days)	Pass Number	Beta Measurement[(a)] (mμc per 100 sq cm)	Per Cent Residual
Fiber Brush	U + 9	0	9,960	100.0
		1	7,940	79.1
		0	7,360	100.0
		1	4,400	60.7
WITHOUT BURNER				
Wire Brush (Solid Fill)	S + 6	0	1,530	100.0
		1	750	49.0
		2	700	45.7
		3	630	41.2
		4	500	32.7
Wire Brush (Knot Type)	S + 7	0	2,030	100.0
		1	1,020	50.0
		2	890	43.4
Wire Brush (Tennant)	U + 10	0	7,700	100.0
		1	6,420	83.4
Revo Tool	U + 9	0	9,840	100.0
		1	7,820	79.5
		2	5,980	60.8
		3	4,480	45.5
		4	3,560	32.2
		5	2,640	26.8
WITH BURNER				
Wire Brush (Solid Fill)	S + 6	0	2,270	100.0
		1	640	30.9
		2	550	24.2
		3	500	22.0
		4	290	12.8
Wire Brush (Knot Type)	S + 7	0	2,630	100.0
		1	990	37.6
		2	830	31.5
Wire Brush (Tennant)	U + 9	0	6,340	100.0
		1	4,520	71.3
Revo Tool	U + 9	0	8,840	100.0
		1	6,240	70.5
		2	4,220	48.0
		3	2,940	33.0
		4	2,100	24.0
		5	1,400	16.0

(a) Beta measurement on Pass No. 0 equals initial level.

TABLE 4.4

Air Sampling Data

Surface Being Decontaminated	Air Sample	Time of Sampling	Period of Sampling	Beta-gamma (d per m per cu ft)	Alpha (d per m per cu ft)
Wood	Background	During Operation		258	<1/Sample
	Burner Exhaust	During Burning Operation	15 min	1,750,000	46.6
	M-6 Filter Exhaust	During Wire Brushing	15 min	430	None
Wood	Burner Exhaust	During Burning Operation	10 min	91,800	11.95
	M-6 Filter Exhaust	During Operation	5 min	1,800	<1/Sample
Wood	Background	During Operation	2 hr	320	0.02
	M-6 Filter Exhaust	During Burning Operation	10 min	4,200	0.44
Asphalt	Background	Prior to Operation	4-5 hr	315	None
	Burner Exhaust	During Burning Operation	15 min	8,900	60.0
Concrete	Background	During Operation	2 hr	20	<1/Sample
	Burner Exhaust	During Burning Operation	15 min	62,000	12.0
	Burner Exhaust	During[a] Brushing Operation		25,000	4.4
	M-6 Filter Exhaust	During Brushing Operation	50 min	48	<1/Sample

[a] Burners were off during this sampling operation.

TABLE 4.5

Decontamination Wastes

Surface	Method	Waste Removed
Wood	Revo Tool, 1st Pass (Runs 7-12)	2 lb or 3 gal per 100 sq ft
	Wire Brush, 1st Pass (with Grain)	1.7 lb or 1.8 gal per 100 sq ft
	Wire Brush, 2nd Pass (with Grain)	1.12 lb or 1.3 gal per 100 sq ft
	Wire Brush, 3rd Pass (with Grain)	0.8 lb or 1.2 gal per 100 sq ft
	Sander Vacuum Cleaning	Not Determined, but Estimated to Yield Considerably More Bulk than Other Two Tools
Asphalt	Vacuum Cleaning	1 to 1.5 qt per 380 sq ft
	Scraper	0.02 to 0.04 cu ft per sq ft (Estimated)
Concrete	Wire Brush	Slightly less than 1 qt per 80 sq ft

TABLE 4.6

Operational Rates and Costs

Surface	Speed (ft/min)	Width Resurfacing Tool (in.)	Decontamination (sq ft/hr/pass)	Propane Expended				Oxygen Expended				Decontamination Rate (sq ft/hr/ft width of resurfacing tool)[c]
				Per Hour		Per 1,000 sq ft		Per Hour		Per 1,000 sq ft		
				Cu Ft	Cost[a] ($)	Cu Ft	Cost ($)	Cu Ft	Cost[b] ($)	Cu Ft	Cost ($)	
Wood	20	15	1,500	56.3	0.55	37.5	0.31	266	2.13	178	1.18	1,200
Asphalt	11	28	1,540	184	1.81	120	1.81	610	4.89	400	3.17	660
Concrete	24	15	1,800	56.3	0.55	31.2	0.25	266	2.13	148	0.99	1,440

[a] Propane costs based on $0.08 per lb.

[b] Oxygen costs based on $0.008 per cu ft.

[c] The decontamination rate given in sq ft per hr per ft of resurfacing tool width is of value in determining the decontamination rate to be expected by a larger size Flaminator. Multiply this rate by the width of the surface removal tool in feet to determine the sq ft per hr per pass.

Fiber brushing and vacuum cleaning rates: wood and concrete, 20 ft per min; asphalt, 15 ft per min.

4.5 DISCUSSION

4.5.1 Wood Decontamination

Twenty hours after the Underground detonation, the dosage rate in Area A was 3 to 10 r per hr. The entire area was covered with a layer of very finely powdered, light-colored dust approximately 1/32 to 1/16 in. thick. Since the radiation field was too high for safe working conditions, a land reclamation team was sent into the area 4 days later to scrape and plow about 40 ft around each side of the wood and concrete strips. By this operation, the dose rate on the test strips was reduced from approximately 1.5 r per hr to 400 mr per hr. This field was still so high that the stay time would have been very short. It was also observed that the area was recontaminated almost daily by dust blown from the Underground Shot crater (see Fig. 4.3).

The wood strips were removed from Area A and reassembled on the northwest missile throwout strip where the radiation level was only 1 to 2 mr per hr. Working in this area proved ideal since the wood strips were still running between 50 and 200 mr per hr with an average of 100 mr per hr. Prior to decontamination, most of the original layer of contaminated dust had been washed from the wood test strip by the rain but after reassembly of the wood sections on the missile fallout strip, a thin layer of light-colored dust still adhered to the entire surface.

Flame treating greatly increased the efficiency of all the surface removal tools. From the data in Table 4.1 it was determined that when using the wire brush or the sander, the oxypropane burner increased decontamination by a factor of 2. Decontamination results for the Revo tool were improved by a factor of 3.5.

The higher reduction in contamination with the use of the burner was a result of two factors: (1) more surface was removed per pass, as shown in the surface removal measurements of Table 4.1; and (2) part of the contaminant was carried off by volatilized material and smoke particles and was discharged from the burner hood (Table 4.4).

In all tests conducted on fir and teak, the wire brush was superior to the Revo tool and sander, both of which gave practically the same results on these two varieties of wood. On the other hand, in the tests on pine, the Revo tool and sander gave better results than the wire brush, since the deeper penetration of the contaminant made greater surface removal necessary. It was noted that a considerable amount of recontamination occurred during sanding operations.

[redacted] Security Information [redacted]

[redacted]

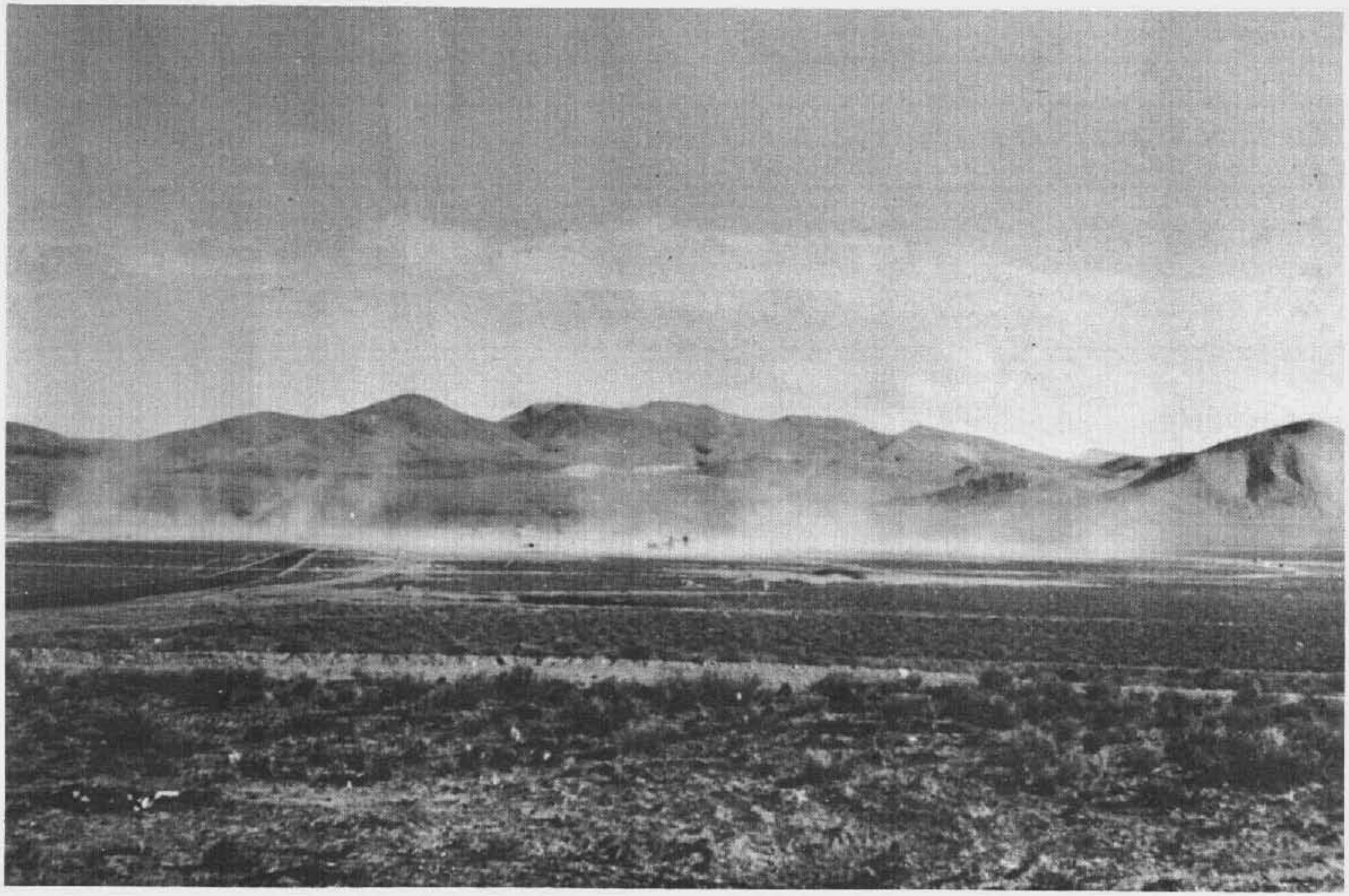


Fig. 4.3 Dust Blowing from Underground Shot Crater (U + 6 days)

[redacted] Security Information [redacted]

The effect of direction of travel (with grain or cross grain) varied with the type of wood and with different surface removal tools. It can be seen from Table 4.1, that, in most cases, with-grain travel gave the highest reduction in contamination.

It will be observed that on fir and teak there was a greater reduction by with-grain travel, and on pine by cross-grain travel. A much larger amount of surface was removed from the pine by cross-grain travel; this condition was particularly evident by visual observation when using the Revo tool. Traveling with grain, this tool pounded and compressed the pine surface, and very little removal was observed. On cross-grain travel, however, this tool chewed into the surface for a considerable depth.

The vacuum cleaning operation, assisted by the fiber brush, reduced contamination by a factor ranging from 1.4 to 3.0 with the first pass on all of the wood surfaces. Until after decontamination with the fiber brush, all three varieties of wood had the same appearance, and one wood could not be distinguished from another. The teak samples were cleaned up much better than the other samples and had a brightly polished appearance after the first pass. After the second pass, no dust was visible on any of the wood surfaces, and the contamination was reduced an additional 10 to 15 per cent.

There is no apparent correlation between the surface removal measurements and the reduction in contamination. This is due principally to the method used in the determination of the amount of surface removed. The surface removal measurements obtained were not a true measure of the amount of surface removed, but were actually measurements from the head of the pin to the averages of the high points over approximately 6 sq in. of surface. When using the wire brush, grooves were cut into the surface, particularly on fir and pine, and the Revo tool compressed the wood by its pounding action; this resulted in erroneous surface removal measurements. When using the sander, the surface removal measurements were reasonably accurate.

Other methods of measuring the amount of surface removal were tried at USNRDL, but an accurate method fast enough for field use was not devised. The individual measurements by the method used, however, were reproducible within 0.002 to 0.003 in.

4.5.2 Asphalt Decontamination

Prior to laying out the test strip, a survey was made of the roadway and it was found that it was possible to obtain readings varying by a factor of 8 for relatively small shifts in the position of the beta probe, depending on whether the probe was over a smooth area or a dust-filled crack or hole. The variation was from 2,800 to 21,000 mμc.

A large portion of the loose contaminated dust had been swept to the shoulder of the road by truck traffic and rain. No previous decontamination had been attempted on this area after the Underground Shot. The dose rate during these tests was 80 to 150 mr per hr.

On one pass, the fiber brush assisted by vacuum cleaning removed most of the loosely held surface contaminant. However, the material in the deep cracks or small holes, and the material tenaciously held on the surface were not picked up by the brush and vacuum. The average residual contamination after fiber brushing was about 37 per cent, as seen in Table 4.2.

The Flaminator equipped with the oxypropane burners and scraper left an average of 3.5 per cent residual contamination (cf Table 4.2). Directly behind the burner hood, the asphalt was soft to a depth of approximately 1 in., but due to cold weather during these tests it resolidified rapidly. Because of this rapid cooling, it was necessary to add considerable weight to the scraper to obtain effective cutting. With the scraper loaded with 400 lb, a layer of asphalt approximately 1/4 to 1/2 in. was removed. In the vicinity of the test area, slight recontamination of the clean asphalt by truck traffic was apparent.

The primary objective of the asphalt tests was to prove that flame softening, followed by scraping, was an effective industrial decontamination method. The speed of decontamination could be greatly increased by increasing the total heat output of the burners and placing the scraper directly behind the burners. A commercial asphalt planer, similar to the Clarkmore asphalt road heater-planer, will plane (or cut) a path 6 ft wide to an average depth of 1/2 in. at a rate of 16,300 sq ft per hr or at a linear speed of 1/2 mph. This unit is used for resurfacing bituminous surfaces (such as sheet asphalt, asphaltic concrete, plant mix, patented mixes, and Trinidad asphalt) by planing the flame softened surface. This planer uses 7 gal of No. 2 fuel oil per hr and 30 gal of gasoline at a total cost of approximately $0.16 per sq yd of surface, and requires one operator. This unit could be used on contaminated surfaces, and virtually complete decontamination would be expected.

4.5.3 Concrete Decontamination

Flame treating increased the efficiency of the Revo tool and all three types of brushes tested on the concrete, as shown in Table 4.3. It was observed that when the solid fill wire brush was used, the reduction in contamination was higher on one pass with the burner than on four passes without. However, when using the Revo tool with the burner, only one less pass was required to reduce the activity to a given value than without the burner. The specific characteristics of the concrete surface made it necessary to operate the Flaminator at a higher speed on concrete than on the wood test strip to avoid glazing the high ridges on the surface. (Glazing the surface is undesirable because it seals in the contaminant.) Previous flame cleaning tests on concrete at the USNRDL gave more effective decontamination than was experienced on this operation. It is believed that on a smooth, well aged concrete surface, the BTU output of the burners could have been increased with a resultant increase in the decontamination efficiency.

Insufficient data were collected to draw any definite conclusions on the efficiency of the various wire brushes as compared to the Revo tool, since only the Tennant wire brush was tested under the same conditions. (Tennant wire brush was the only brush tested after the Underground Shot.)

The Tennant wire brush gave a lower reduction in contamination than the Revo tool. It is believed that the solid fill wire brush would have given better results. The Tennant brush is an open-type brush which is wrapped around the hub to form a spiral. The waste is fed to the side of the vacuum hood by this brush. Considerably more vacuum is required to remove the waste than with the solid fill brush which throws the waste into the vacuum hood as it is loosened.

The first pass with all of the tools removed a higher percentage of contamination than succeeding passes, because on this pass the loosely held contaminant on the surface was removed. Upon comparison of the fiber brush and Revo tool data in Table 4.3, it will be observed that the initial level on these two runs was approximately the same, with the fiber brush giving approximately the same percentage decontamination on the first pass as the Revo tool. It is believed, however, that as was the case with the wood test strips, using the fiber brush for more than one pass would not appreciably reduce the level achieved by the first pass.

4.5.4 Personnel Hazard

The present Atomic Energy Commission (AEC) tolerance for continuous breathing of beta-gamma contamination for one year is 63 d per m per cu ft or 630,000 d per m per cu ft for 24 hr continuous breathing. The tolerance for continuous breathing of alpha contamination for one year is 0.32 d per m per cu ft.

The gases discharged from the burner exhaust pipe exceed the tolerance for continuous breathing for one year by a considerable amount, but insufficient data were collected to determine the seriousness of the personnel hazard.

It will be observed by a study of the data in Table 4.4 that during operations on the wood and concrete surfaces, the background count was less than or only equal to that obtained in the vicinity of the asphalt test area prior to the decontamination work.

The count obtained on the burner exhaust during the decontamination of the wood strips was much higher than that obtained on the asphalt and concrete. A large amount of contaminant was concentrated between the boards on the wood strips, and it is believed that this material was blown loose by the jet action of the oxypropane flame.

The values obtained on the exhaust from the M-6 filter are not necessarily an evaluation of the efficiency of the M-6 filter because of the sampling method used. The air sample was located approximately 6 in. from the M-6 filter and 2 to 2-1/2 ft above the surface removal tool. It is quite possible that a small amount of the material removed by this tool escaped the collection hood and reached the air sampler; some of the material discharged from the burner hood may have also been picked up by this air sampler at the rear of the machine. The counts obtained on the filters from this sampler, however, were not appreciably higher than the background.

Although the results obtained by air sampling are not conclusive, it was shown that a considerable amount of contamination was discharged from the burner hood. It is desirable that the Flaminator operator wear an efficient respirator.

4.5.5 Additional Observations

Some equipment and packing boxes were removed from Area A at the time the wood sections were transported to the northwest missile throwout strips. The various items had been covered by a tarpaulin prior to the Underground detonation and had remained covered during the contaminating event and rainstorm. The tarpaulin showed 300 to 500 mr per hr while the equipment and boxes showed a dose rate of only 3 to 5 mr per hr when moved from the contaminated area.

Radiological safety "protective" clothing was very inadequate for this particular operation. Upon completion of the day's work, it was found that the knees of the operators' underclothing were very highly contaminated from kneeling to take the depth measurements. Holes were worn in the bootees in a few hours, resulting in highly contaminated shoes at the end of each day.

4.6 CONCLUSIONS

The basic idea of the Flaminator is sound, and upon expansion to a full scale model it can be developed into a practical, operational decontamination unit.

Flame cleaning (treating) in combination with surface removal tools is a very effective method of decontaminating wood, asphalt, and concrete. Flame treatment of wet wood surfaces makes it possible to use surface removal methods of decontamination which might otherwise be ineffective.

The effectiveness of all surface removal tools is greatly increased by prior treatment with the flame.

The Flaminator when equipped with only two different tools (wire brush and scraper) will effectively decontaminate wood, asphalt, and concrete surfaces, i.e., wire brush for wood and concrete, and scraper for asphalt.

Sweeping (fiber brushing) assisted by vacuum cleaning is a fairly effective tactical decontamination method, but since the rates of operation are about the same as for surface removal, the use of flame cleaning equipment, if available, is preferred.

No apparent hazard is involved in the maintenance of the Flaminator, but during operations the operator should be protected by an efficient respirator.

Radiological safety protective clothing was inadequate for this particular operation.

Supplies and bulk materials can be protected from contamination while in storage by covering with tarpaulins.

4.7 RECOMMENDATIONS

Investigate the possibility of increasing the Flaminator operating speed on wood and concrete by the application of improved burners and fuels.

Test the experimental Flaminator aboard an aircraft carrier flight deck to determine the effectiveness of flame cleaning and surface removal methods on payed decking. Prepare design specifications for a full scale Flaminator for use on flight decks and other wood surfaces.

Investigate the adaptability of commercial asphalt road working equipment, such as the Clarkmore heater-planer, for use in contaminated areas. Prepare design modifications if necessary, so that such equipment can be prepared for the Armed Forces on the shortest possible notice.

Conduct laboratory tests on various grades and types of concrete surfaces to establish the factors involved in the effective decontamination by flame cleaning and surface removal.

Develop methods of stabilizing the crater resulting from an Underground detonation, thus reducing the possibility of recontamination.

Plan an underwater contaminating event in which both liquid methods and surface removal methods are used in the decontamination of various types of ship decking or simulated decking, complete with payed joints.

CHAPTER 5

DECONTAMINATION OF PAVED AREAS

J. C. Maloney

5.1 INTRODUCTION

This is a report on a series of field tests which were conducted at Operation JANGLE to evaluate equipment and techniques for decontamination of paved areas which had become contaminated as the result of surface and underground atomic bomb detonations.

The contamination of the test area was the result of:

1. Fall-out, and/or base surge; and/or throw-out effected by both a surface and an underground detonation.

2. Transport of the contaminant to the test surfaces by winds and the operations of personnel and vehicles.

The test results can be used in the formulation of field procedures, using available equipment, for the decontamination of paved areas.

5.2 OBJECTIVES

The field test was undertaken:

1. To determine the merits of various decontamination methods and equipment, and the speed with which, in each case, superficial contamination can be removed from paved roads.

2. To investigate the external and internal personnel hazards associated with each decontamination method.

3. To establish the manpower and protective equipment requirements for each decontamination method.

5.3 PROCEDURES

5.3.1 Test Surfaces

All decontamination studies were performed on a road that had been made by compacting a mixture of rock and bituminous liquid. Individual road sections, 50 ft long and approximately 15 ft wide, were chosen for the evaluation of each decontamination procedure. Each section was subdivided into four rows of 10 rectangles each, the rectangle size being approximately 4 ft wide and 5 ft long.

5.3.2 Methods and Equipment

The following decontamination methods and decontamination equipment were tested:

Method	Equipment
Dry Sweeping	Sweeper, rotary broom, trailer mounted, traction power
Vacuum Cleaning	35-HP Spencer vacuum cleaner
Air Hosing	315-cfm Schramn air compressor
Water Sprinkling	Decontamination truck (apparatus, decontamination, power driven, M3A1)
Low Pressure Hosing	10-gpm pump and garden hose
High Pressure Hosing	Decontamination truck
Wet Sweeping	Sweeper, rotary broom with improvised spray bar
Air and Water Hosing	315-cfm Schramm air compressor and 10-gpm water pump

An experimental portable beta probe developed by USNRDL was used to measure beta intensity on the paved surfaces. At 3-ft and 6-ft levels above the surface, gamma intensity readings were taken with a Raychronix Model D-1A beta-gamma survey meter ("Cutie Pie") with the end window closed. Detailed information on the USNRDL instrument is given in Chapter 11.

5.3.3 Test Procedure

The various decontamination procedures were applied to roads in the northwest quadrant of the Underground Shot area, 2,000 ft to 1 mile from ground zero. This work, which was done as soon after the bomb detonations as permitted by the Radiological Safety Group, started at the greater distance from ground zero and progressed toward ground zero as radiation decay allowed safe access.

Each procedure was evaluated as follows:

1. Intensity readings were taken at the center of each of the 40 rectangles with the probe in contact with the surface. (A rope with markers at 5-ft intervals was stretched along the road shoulder to guide the placing of instruments). The surface readings are expressed in microcuries for approximately 100 sq cm of surface. In addition, gamma readings were taken at 3-ft and 6-ft heights above the mid-point of the rectangle sides lying along the road centerline. The surface readings are used in evaluating decontamination efficiency, while the gamma readings above the road are a measure of the radiation hazard to personnel whether afoot or in vehicles.

2. Each procedure was applied for a predetermined time interval.

3. Each test area was resurveyed to determine~~d~~ the decontamination achieved.

Time and manpower requirements were determined for each operation. In several operations, Steps 2 and 3 were repeated to ascertain whether or not a stable level of residual contamination, for the particular technique employed, had been reached.

5.3.4 Procedure for Determining Personnel Hazard

The external and internal personnel hazards associated with each decontamination procedure were determined as follows:

1. Operating personnel were equipped with special film badges to record the dosages incurred during the decontamination process.

2. Operating personnel were monitored periodically to determine the amount of radioactive materials deposited on their clothing.

3. Air samples were taken in the vicinity of the operators during representative operations to determine the airborne activity. The radiation intensity on respirator filters used during representative operations was also determined.

5.4 TEST RESULTS

Tables 5.1 and 5.2 show the mean initial and final radiation intensity readings for each decontamination operation.

Tables 5.3 and 5.4 show: (1) decontamination efficiencies, (2) percentage reductions in intensity at the 3-ft and 6-ft levels, and (3) equipment hour requirements for each operation.

TABLE 5.1

Decontamination Data for Surface Shot[a]

Date	Method of Decontamination	Surface Contamination (μc)		Gamma Intensity above Road, 100 mr/hr			
				At 3-ft Level		At 6-ft Level	
		Initial	Final	Initial	Final	Initial	Final
22 Nov	Vacuum	6.7	6.1	0.7	0.6	0.7	0.6
22 Nov	Air Hose	5.5	3.7	0.4	0.4	0.4	0.4
24 Nov	High Pressure Hose	3.0	0.3	0.4	0.1	0.4	0.1

[a] All values corrected for background. The readings shown for surface contamination are the arithmetical average of 40 readings; other values are the average of 10 readings.

TABLE 5.2

Decontamination Data for Underground Shot

Date	Method of Decontamination	Surface Contamination (μc)		Gamma Intensity above Road, 100 mr/hr			
				At 3-ft Level		At 6-ft Level	
		Initial	Final	Initial	Final	Initial	Final
30 Nov	Vacuum	29	16	2.3	1.2	1.6	1.2
30 Nov	Dry Sweep	30	6	2.2	0.7	1.5	0.7
1 Dec	Wet Sweep plus Water Rinse[a]	17 17	11 2	0.9 0.9	0.8 0.6	0.7 0.7	0.6 0.6
30 Nov	Water Sprinkle	22	11	1.5	1.1	1.1	0.9
1 and 3 Dec	High Pressure Hose 5.5 min 11 min 13 min	18 18 16	6 0.9 0.4	1.2 1.2 1.0	1.0 0.9 0.5	1.2 1.2 0.8	1.1 1.0 0.5
3 Dec	Low Pressure Hose	24	4	1.8	1.3	1.7	1.4
30 Nov and 3 Dec	Air Hose 7 min 11 min 15 min	10 10 32	3 1 2	1.1 1.1 2.5	0.7 0.8 0.3	1.2 1.2 1.8	0.9 0.9 0.7
4 Dec	Air and Water Hose	6.0	[illegible]	0.6	0.5	0.6	0.5

[a] Sufficient water, from low pressure nozzle, to carry loosened contamination off of road.

TABLE 5.3

Summary of Results for Surface Shot(a)

Date	Method of Decontamination	Area per Equipment Hour (1, 000 sq ft)	Surface Decontamination Effected (per cent remaining)	Reduction in Gamma Intensity (per cent remaining) At 3 Ft	At 6 Ft
22 Nov	Vacuum	1.7	91(---)(b)	86(98.8)(b)	86(---)(b)
22 Nov	Air Hose	5.0	67(86.9)	(---)	(---)
24 Nov	High Pressure Hose	1.5	13(32.3)	33(20.6)	25(28.0)

(a) These results are influenced by prior weathering (high winds for one day plus a rainfall of several hours duration).

(b) The percentages shown in parentheses are the corresponding statistically derived values with a probability confidence level of 95 per cent. These were derived using the "t-test for difference of means".

TABLE 5.4

Summary of Results for Underground Shot

Date	Method of Decontamination	Area per Equipment Hour (1, 000 sq ft)	Surface Intensity Reduction (per cent remaining)	Reduction in Gamma Intensity (per cent remaining) At 3-ft Level	At 6-ft Level
30 Nov	Vacuum	1.7	55(62.4)(a)	51(56.6)(a)	75(78.0)(a)
30 Nov	Dry Sweep	2.0	17(24.4)	32(36.4)	47(55.4)
1 Dec	Wet Sweep	1.5	65(79.0)	89(89.1)	86(93.5)
	plus Water Rinse	0.8	13(21.9)	67(67.7)	86(85.2)
30 Nov	Water Sprinkle(b)	3.3	50(54.6)	73(76.4)	82(88.9)
1 and 3 Dec	High 5.5 min	4.0	34(86.3)	83(99.95)	92(99.98)
	Pressure 11 min	2.0	5.0(57.6)	75(84.9)	83(91.5)
	Hose 13 min	1.7	2.0(12.3)	50(51.4)	63(71.6)
3 Dec	Low Pressure Hose	0.9	16(23.1)	73(80.0)	82(87.9)
30 Nov and 3 Dec	7 min	3.3	30(35.4)	64(69.2)	75(76.8)
	Air Hose 11 min	2.0	10(21.3)	70(74.1)	75(79.6)
	15 min	1.5	6.0(17.7)	12(19.4)	38(45.2)
4 Dec	Air and Water Hose Hose(c)	1.1	67(73.0)	83(85.1)	83(87.5)

(a) Statistically derived; see Table 5.3, note (b).

(b) Due to the shortage of water at the test area, a truckload of water with 0.3 per cent solution of Tide, a household detergent, was utilized.

(c) Due to malfunctioning of survey instruments, the initial readings had to be retaken on the adjacent stretch of road subsequent to decontamination operation. These results are considered fairly reliable however.

TABLE 5.5

Airborne Hazard Data[a]

Operation	Date (Days)	Type Evaluation	Alpha (µc per liter)	Beta (µc per liter)
High Pressure Hosing	S + 5	Air Sampler	8.2×10^{-9}	7.2×10^{-6}
		Respirator (Operator)	0	1.0×10^{-6}
		Respirator (Control)	1.1×10^{-9}	2.6×10^{-6}
Air Hosing	S + 3	Respirator (Operator)	1.8×10^{-8}	8.9×10^{-6}
		Respirator (Control)	6.3×10^{-9}	2.3×10^{-5}
Dry Sweep	S + 3	Air Sampler	2.0×10^{-8}	5.6×10^{-4}
Wet Sweep	U + 2	Air Sampler	1.8×10^{-8}	2.7×10^{-4}

(a) **Values are not corrected for decay. During both sweeping operations the air sampler was mounted on the brushing trailer. Sample is not representative of air an operator would breathe.**

No dosage differential, resulting from the various decontamination processes, was detected on special film badges worn by operating personnel. However, since the individual dosage limitation of 3 r for the duration of the combined Operation BUSTER/JANGLE limited this investigation to areas of relatively low-level contamination, the operations involved could result only in minor differences in dosage.

Usually no clothing, with the exception of bootees and gloves, was contaminated beyond the specified radiological safety tolerance.

Table 5.5 is a compilation of air sampler and respirator filter data for the various operations. The results are inconclusive due to the small number of samples taken and the limited scope of each test; however, there is no indication of serious internal hazard associated with these operations.

5.5 DISCUSSION

5.5.1 Limitations

Subsequent to the Surface Shot and prior to the start of decontamination operations, high winds and a rainfall of several hours duration removed essentially all loose contamination from the test road so that all wipe tests were negative.[1] In consequence of this weathering,

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[1] This wipe test was performed by wiping the paved surface with a pad of cotton gauze and then determining the amount of loose radioactive contamination on this pad by using a "Cutie Pie" survey meter.

the gamma field intensity, at a height of 3 ft above the center of the road and also above the upwind shoulder of the road, had been reduced by about 50 per cent. This would account for some of the wide disparity between the Surface and Underground Shot test results.

In general, the many variables encountered in these tests precluded the production of accurate quantitative data. The 40 intensity readings, varying from 2 to 16 μc, shown in Table 5.1 as an example for a single test section, should be used as a basis for qualitative conclusions only.

5.5.2 Effectiveness of Procedures

Of all the procedures tested, high pressure hosing was the most effective, although the air hosing, dry sweeping, and low pressure hosing were also very efficient.

The best procedure, from the standpoint of speed and effectiveness, appears to be water hosing at the highest available pressure. Of course, this procedure is limited to areas having an adjacent, adequate water supply system.

In areas where the use of water is not practical, dry sweeping or air hosing procedures must be used. A street sweeper truck, preferably with debris pickup and hopper, is recommended.

5.5.3 Reduction in Radiation Levels

The observed intensity at the 3-ft and 6-ft heights above a surface after its decontamination frequently could not be correlated with the surface intensity reduction. These inconsistencies are, of course, to be expected in view of the nature of these tests.

The radiation intensity above the road after decontamination obviously depends on:

1. The disposition of the contaminant—whether it is collected in vacuum cleaner tanks or merely moved to the road shoulders.

2. The re-deposition of wind-carried contaminated dust resulting from dry operations.

3. The resettling of the runoff resulting from wet operations according to the topography of the area.

During the dry sweeping operations, a dense dust cloud was generated which hovered in the vicinity of the brush and its shield. This dust on resettling would account for some of the contamination on the road after the operation. It is therefore recommended that an evaluation be made of the use of vacuum to remove this dust cloud. Sweeping with a wet brush does eliminate the dust cloud but is not a satisfactory method of decontamination unless followed by a water rinse (see Table 5.2).

The relationship between decontamination efficiency on a surface and the intensity reduction above this surface at the 3-ft and 6-ft levels would be influenced by the redeposition pattern which in turn depends upon the terrain features and wind.

5.5.4 Protective Equipment and Manpower Requirements

For dry operations, an ample supply of standard fatigue clothing and dust respirators should be available. Wet operations should be performed with rubberized clothing, heavy rubber gloves, knee length rubber boots, head covering, and face shield for protection against spray, mud, and runoff water.

Manpower requirements for the various decontamination methods did not vary significantly. It is expected that on larger scale operations, dry sweeping would require minimum manpower.

5.6 CONCLUSIONS AND RECOMMENDATIONS

5.6.1 Decontamination Methods

High pressure water hosing was most effective. However this requires an adequate, adjacent water supply or a more economical use of water brought in by equipment such as the M3A1 power driven decontaminating apparatus. Flooding the road with low velocity water did not produce satisfactory results. A commercially available street flusher, equipped with high pressure water jets should be satisfactory.

High pressure hosing with air was very effective but had the disadvantage of spreading the contamination in the form of a dust cloud.

The least effective decontamination was obtained by using the large vacuum cleaner, without accompanying brushing. However, it must be emphasized that improved performance should be easily obtained by redesigning this unit.

5.6.2 Operating Procedure

It is recommended that adequate drainage from the road shoulders be provided for any wet operation. A small ditch about 2 ft deep and 1 ft wide serves the purpose. This should be filled in after the roadway decontamination to shield and immobilize the deposited radioactive material.

5.6.3 Personnel Safety

No significant activity was detected on protective clothing worn by members of the test group. Bootees and gloves were discarded at the end of each day; all other protective clothing was worn for several days before being discarded. Larger scale operations and/or operations in areas of much higher radiation intensity, on the other hand, could result in significant contamination of the protective clothing.

Gamma shielding may be required for personnel engaging in extended decontamination operations. Studies on the shielding afforded by vehicles are described in Chapter 10.

5.6.4 Suggestions for Future Tests

The following decontamination methods and equipment should be evaluated:

1. Dry brushing with vacuum pickup.
2. Air hosing with vacuum pickup.
3. Road patrol sweeper (uses device to automatically transfer debris).
4. Street flusher.
5. Fire hosing.

Techniques, after showing promise in preliminary tests should be tested on a larger scale, perhaps on a 500-ft stretch of roadway.

Provisions should be made for burial or disposal of radioactive waste as it is concentrated or collected during decontamination procedures. Burial in ditches along the road appears to be a suitable solution.

CHAPTER 6

DECONTAMINATION OF TEST STRUCTURES

George L. Smith, Jr.

6.1 ABSTRACT

An attempt was made to apply in the field three common decontamination methods (fire hosing, hot liquid cleaning, and vacuum cleaning) to the removal of radioactive contaminant from the exterior surfaces of three experimental buildings. Measurements were made to determine field effectiveness, rates of performance, and hazards. The effects of typical surfaces and geometrics upon these factors were also investigated.

It was determined that a combined method of vacuum cleaning followed by hot liquid cleaning was most effective, resulting in an average reduction of the contamination level by a factor of six.

The shape of the building surfaces appeared to have a greater effect on decontamination than the nature of the surface material. Personnel hazards were not significantly greater because of decontamination operations.

6.2 OBJECTIVES

These experiments on the decontamination of test structures had three major objectives:

1. To determine the effectiveness of three cleaning methods: water washing with fire hose; hot liquid cleaning with a mixture of steam, hot water, and detergent; and vacuum cleaning.

2. To evaluate the relative effectiveness of various surface protective coatings in minimizing contamination and/or facilitating decontamination.

3. To determine time and man power requirements for each of the methods.

In addition, information was to be gathered pertaining to: individual and team health hazards inherent in the methods; disposal of contaminated waste resulting from the methods; and effectiveness of team training.

6.3 PROCEDURE

The experiments were carried out on three test buildings after the Underground Shot. The buildings were located at a distance of one mile in the direction N 10 deg W. The test procedure consisted of two major steps:

1. Preparing the structures and their surfaces before the Underground Shot.

2. Decontaminating the structures.

Accompanying procedures were: (1) Taking activity measurements of surfaces after the atomic bomb detonation and after decontamination; and (2) taking additional data regarding time-manpower requirements, health hazards, and waste disposal.

6.3.1 Preparing the Structures and Their Surfaces

6.3.1.1 Description of Structures

The general appearance and location[1] of the three test structures are shown in Figs. 6.1 and 6.2. Two of the buildings (designated Buildings 1 and 2) were standard, basic steel magazines, 14 ft by 20 ft (designated by the Bureau of Yards and Docks as Advanced Base Equipment No. MP-10B2). These structures were received in used condition. Each building had one open end. The closed end on Building 1 consisted of prefabricated vertical sheet metal panels. The closed end of Building 2 was framed and sheathed with horizontal drop siding. Building 3 was a small wood frame structure measuring 10 by 12 ft and 6 ft high and was constructed at USNRDL. Window and door openings were provided. The roof had the normal flat roof pitch and was provided with a parapet on half of the perimeter.

6.3.1.2 Preparing the Building Surfaces

The two magazines (Buildings 1 and 2) had been previously painted but in several places required scraping and wire brushing to remove rust, scale, and old paint. The wooden structure (Building 3) had been previously coated with a varnish type wood sealer.

Field surface treatments of sections of the three structures are shown in Fig. 6.3 and in the legend of Fig. 6.4.

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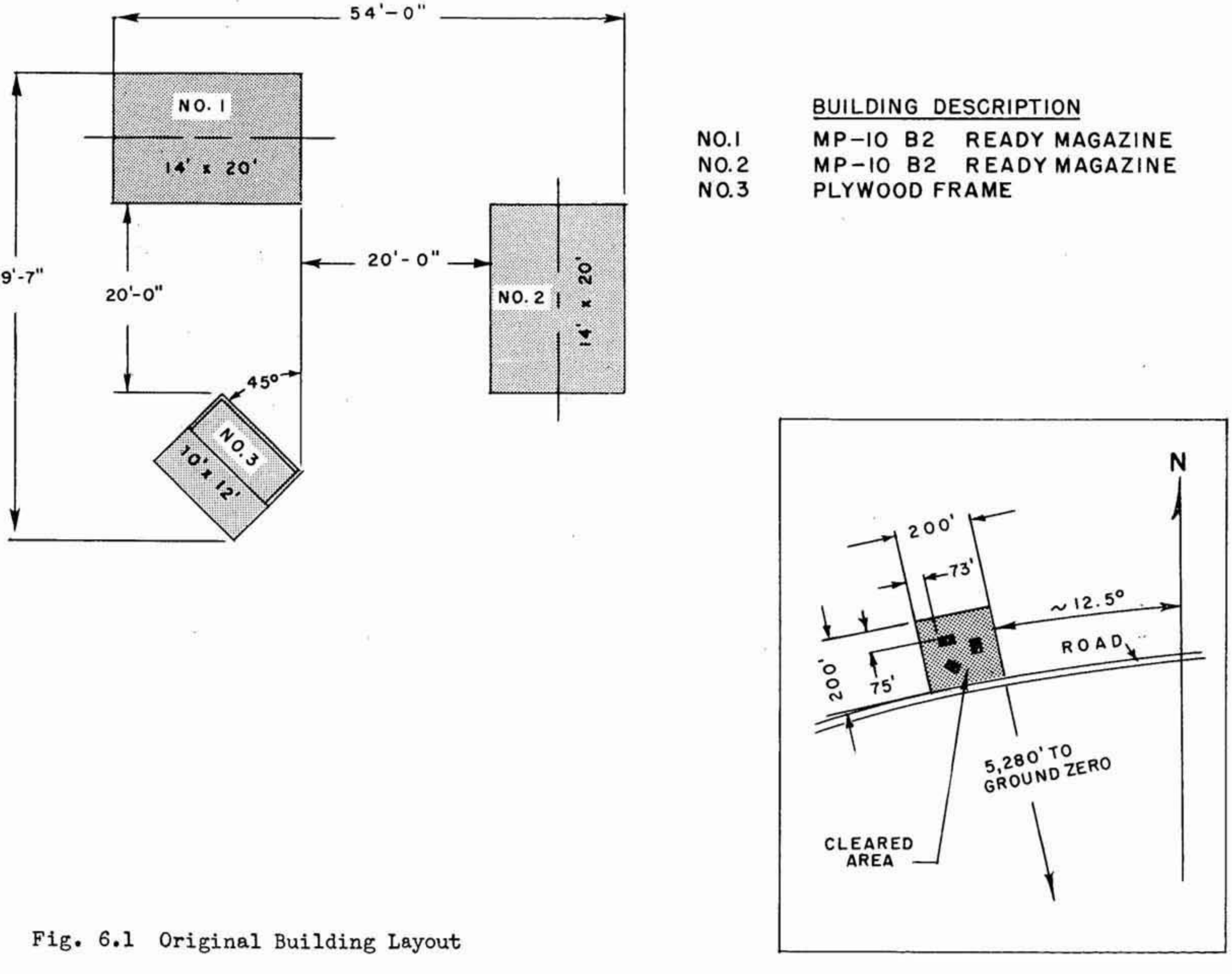
[1] After the burst, it was found necessary to relocate the buildings. (See Section 6.5.4.)



BUILDING DESCRIPTION

NO. 1	MP-10 B2 READY MAGAZINE
NO. 2	MP-10 B2 READY MAGAZINE
NO. 3	PLYWOOD FRAME

Fig. 6.1 Original Building Layout

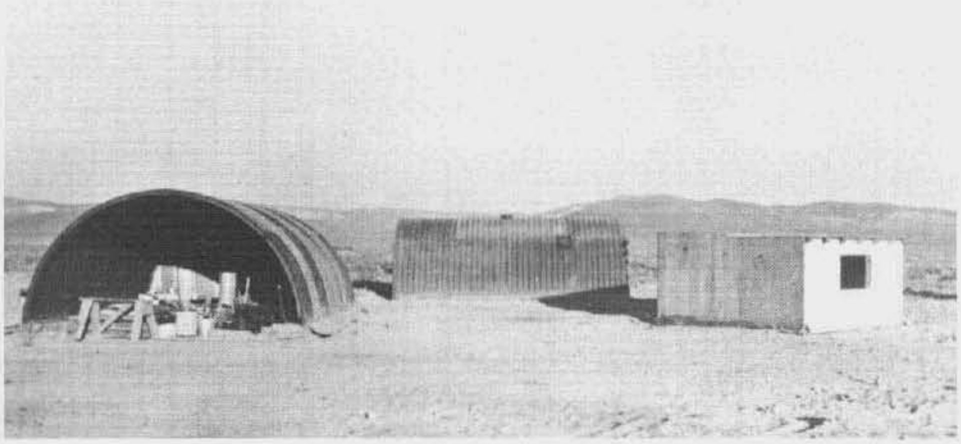
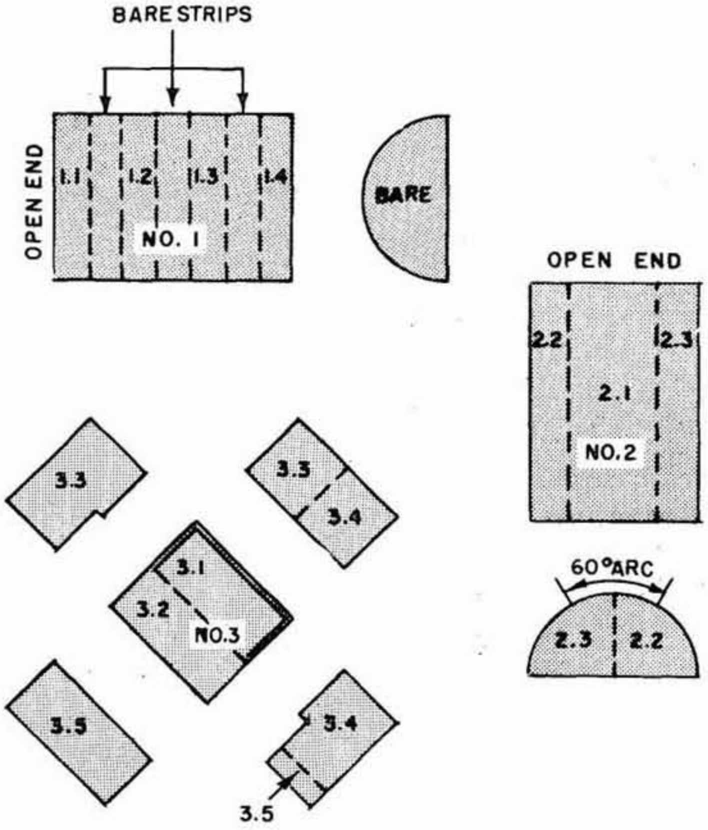


Fig. 6.2 Test Structures in Cleared Area
(L to R: Bldgs 1, 2, and 3)

Fig. 6.3 Preparing the Building Surfaces



FIN. NO.	FINAL FINISH COATINGS	REMARKS
1.1	STRIPPABLE COAT	36-IN. STRIPS
1.2	ARMY O D	↓
1.3	ZINC CHROMATE	
1.4	NAVY 5 H	
2.1	TAR AND GRAVEL	60° ARC ONLY
2.2	NAVY 5H	
2.3	ARMY O D	
3.1	TAR AND GRAVEL	PARAPET $\frac{1}{2}$ ONLY
3.2	ROOFING PAPER	✵
3.3	B 72 ACRYLIC	
3.4	NAVY 5H	
3.5	ASBESTOS SHINGLES	

✵ COVERS EAVE-HALF AND EXTENDS PART WAY UNDER TAR AND GRAVEL

Fig. 6.4 Building Surface Treatment Schedule

These treatments include Navy and Army standard paint, a strippable coating, a prime coat, and a varnish. Roofs were surfaced with tar-and-gravel mixture and with roofing paper.

A portion of Building 3 was covered with asbestos siding.

6.3.2 Decontaminating the Structures

Although some variations and combinations of techniques were employed, the decontamination methods can be considered as three general operations: (1) fire hosing (washing with cold fresh water); (2) hot liquid cleaning (cleaning with a mixture of hot liquid and detergent using a Sellers injector designed for the U. S. Navy Bureau of Ships); and (3) vacuum cleaning.

These three decontamination methods and the basic waste disposal technique employed are illustrated in Fig. 6.5. The decontamination schedule is given in detail in Table 6.1.

TABLE 6.1

Decontamination Schedule

Method and Technique	Surface Decontaminated
Vacuum cleaning with 15-in. brush	On crests, top half of Building 1
Vacuum cleaning with 3-in. brush	In troughs, top half of Building 1
Fire hosing	Top half of Building 1
Fire hosing + wet scrubbing	Building 1, from arch joint to foundation channel. South wall scrubbed; all of building fire-hosed
Hot liquid jet cleaning	Building 2, all
Hot liquid jet cleaning + wet scrubbing	West wall scrubbed, all of building cleaned with hot liquid jet
Vacuum cleaning with 15-in. brush	Building 3, all of roof
Vacuum cleaning with 3-in. brush	Building 3, back of parapet section only

TABLE 6.1 (Continued)

Decontamination Schedule

Method and Technique	Surface Decontaminated
Vacuum cleaning with 15-in. brush	Building 3, all four walls
Vacuum cleaning without attachments	Building 3, parapet section, roof (excess and loose gravel)
Vacuum cleaning with 15-in. brush	Building 3, all of roof
Vacuum cleaning with 3-in. brush	Back of parapet section only
Vacuum cleaning with 15-in. brush	Building 3, all four walls
Hot liquid jet cleaning	Building 3, all exterior surfaces

6.3.3 Accompanying Procedures

6.3.3.1 Measurement of Contamination Levels

Before and after decontamination operations, radiation level surveys were made at preselected survey points with a proportional beta counter (see Chapter 11). Where gamma fields existed which were beyond the range of the beta probe (roof of Building 3, and tar and gravel on Building 2), a field survey instrument (AN/PDR-27c) was used. Readings of the two instruments were correlated by means of a series of measurements on the roof of Building 3 in which both instruments were employed.

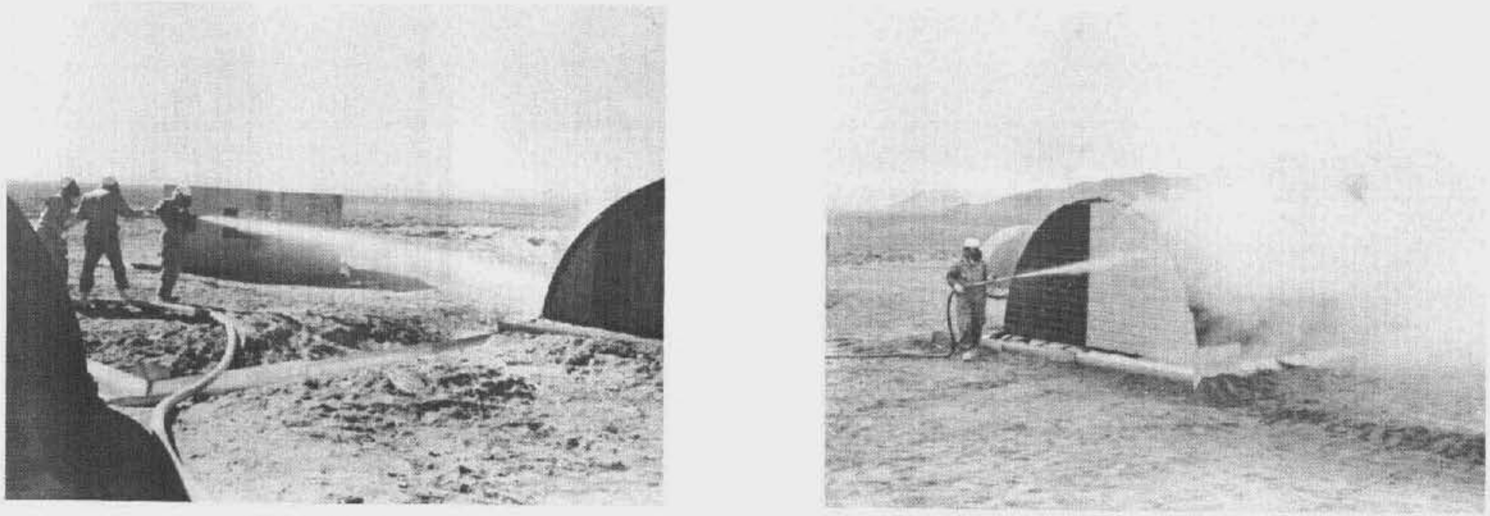
6.3.3.2 Taking Additional Data

During all field tests, approximations were made of the time required to connect equipment, time required to start and warm up equipment, and time required for each cleaning operation.

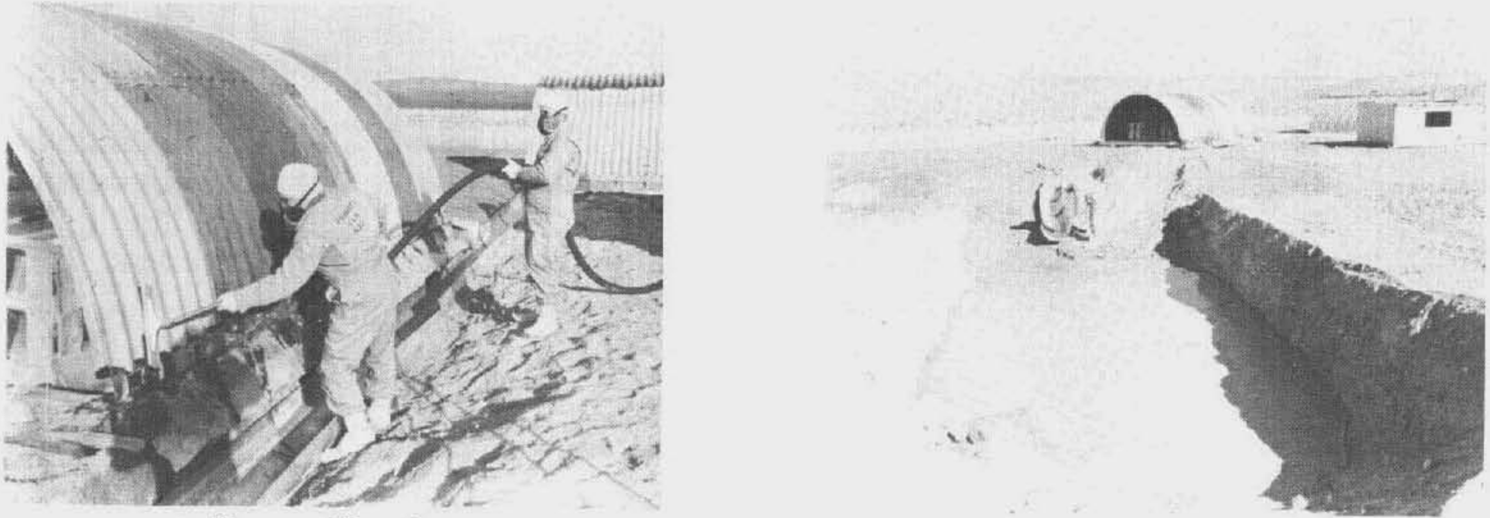
Man power requirements were judged as follows:

1. Was the available man power sufficient to enable the operations to be satisfactorily completed with the existing equipment?

2. Could the available man power be utilized more efficiently with additional equipment or with equipment of more suitable design?



Fire Hosing **Hot Liquid Jet**



Vacuum Cleaning **Liquid Waste Disposal**

Fig. 6.5 Decontamination Methods and Waste Disposal

During all operations, the air was sampled by members of the instrumentation team using equipment described in Chapter 11. Samples were also taken of runoff water (Fig. 6.5) during liquid cleaning methods, except those used on Building 3.

6.4 RESULTS

6.4.1 Effectiveness of Methods

The results of the decontamination methods, singly or in combination, are presented in Tables 6.2 through 6.6. In these tables, the values in milli-microcuries (m µ c) are based on an instrument probe window of 100 sq cm.

TABLE 6.2

Fire Hosing Results(a)

Surface Decontaminated	Activity before Decontamination (m µ c)	Activity after Decontamination (m µ c)	Contamination Remaining (per cent)
Steel, Weathered, Galvanized	700	327	46
	6,000	545	9
	2,000	736(b)	36
	4,000	314	8
	2,200	1,186	54
	1,750	1,128	70
	2,400	968	40
	1,400	859	61
	2,600	1,500	60
Steel, Unpainted, Galvanized	230	82(b)	36
	230	68	29
	290	95	33
	300	109	36
Paint, Navy 5H	1,000	491	49
	450	327	73
	700	382	55
	400	204	50
	1,000	450	45
Paint, Army OD	1,600	831(b)	52
	400	272	68
	840	354	42
	400	204	50
	1,000	491	49

TABLE 6.2 (Continued)

Fire Hosing Results(a)

Surface Decontaminated	Activity before Decontamination (m μ c)	Activity after Decontamination (m μ c)	Contamination Remaining (per cent)
Strippable Coat	2,100	845(b)	40
	1,250	545	44
	4,400	2,045	44
	2,550	1,118	44
	2,550	1,362	53

(a) Two applications.

(b) Reading after first hosing was lower than reading after second hosing, a discrepancy discussed in Sec. 6.5.

TABLE 6.3

Hot Liquid Cleaning Results(a)

Surface Decontaminated	Activity before Decontamination (m μ c)	Activity after Decontamination (m μ c)	Contamination Remaining (per cent)
Paint, Army OD	480	110	23
	420	80	19
	600	160	27
	580	90	16
	260	200	77
	800	180	25
	760	200	26
	680	210	30
	600	240	40
	620	200	32
	660	60	9
	1,800	100	6
	760	80	10
	680	60	9
Paint, Navy 5H	420	80	19
	400	40	10
	580	60	10
	580	70	12
	640	120	19

TABLE 6.3 (Continued)

Hot Liquid Cleaning Results[a]

Surface Decontaminated	Activity before Decontamination (m μ c)	Activity after Decontamination (m μ c)	Contamination Remaining (per cent)
Paint, Navy 5H (Continued)	600	90	15
	480	50	10
	560	50	9
	480	50	10
	420	40	10
	1,800	90[b]	5
	740	50	7
	680	50	7
	620	30	5
	(mr/hr)	(mr/hr)	
Tar and Gravel	135	12	9
	190	11	6
	110	10	9
	200	10	5
	150	23	15

[a] Two applications.

[b] First application of method gave lower result than the second application. This discrepancy may be due to geometry, instrument failure, localized "hot" spot, or related factors.

TABLE 6.4

Vacuum Cleaning Results[a]

Surface Decontaminated	Activity before Decontamination (m μ c)	Activity after Decontamination (m μ c)	Contamination Remaining (per cent)
Paint, Navy 5H	1,450	282	19
	1,250	282	22
	2,150	517	24
	2,150	729	34
	1,550	305	19
	1,550	282	18

TABLE 6.4 (Continued)

Vacuum Cleaning Results(a)

Surface Decontaminated	Activity before Decontamination (m μ c)	Activity after Decontamination (m μ c)	Contamination Remaining (per cent)
Paint, Navy 5H	2,650	305	12
	2,550	305	12
	4,300	1,000	23
	4,700	1,000	20
	650	700(b)	108(b)
Paint, Army OD	9,500	1,600	17
	500	840(b)	168(b)
	3,500	1,000	28
Paint, Zinc Chromate	8,000	1,600	20
	650	900(b)	138(b)
	1,700	1,300	80
Strippable Coat	4,000	2,100	52
	3,300	4,400(b)	133(b)
	4,500	3,000	66
Steel, Galvanized, Weathered	7,500	2,400	32
	2,750	1,400	51
	4,000	2,600	65
Shingles, Asbestos	4,450	2,125	48
	1,750	540	31
	450	235	52
	500	235	47
	550	294	53
	600	294	49
	350	235	67
	550	352	64
	650	470	72
	400	352	88
	450	411	91
	(mr/hr)	(mr/hr)	
Tar and Gravel	460	100	22
	460	100	22
	450	201	45

TABLE 6.4 (Continued)

Vacuuming Cleaning Results[a]

Surface Decontaminated	Activity before Decontamination (mμ c)	Activity after Decontamination (mμ c)	Contamination Remaining (per cent)
Roofing Paper	34	18	53
	41	24	59
	39	20	51
Drain Pipe	250	83	33

(a) Two applications.

(b) Reading questioned. Discrepancy may be due to geometry, instrument failure, localized "hot" spot, or related factors.

TABLE 6.5

Results for Vacuum Cleaning Followed by Sellers Cleaning

Surface Decontaminated	Activity before Decontamination (mμ c)	Activity after Decontamination (mμ c)	Contamination Remaining (per cent)
Paint, Navy 5H	1,450	48	3
	1,250	48	4
	2,150	64	3
	2,150	64	3
	1,150	32	2
	1,150	32	2
	2,650	80	3
	2,550	274	11
	2,550	274	11
	2,450	177	7
	1,150	80	7
	1,950	129	7
	950	80	9
	1,150	64	6
	950	80	9
	550	80	15
	400	80	20
	650	64	10
	500	64	13

TABLE 6.5 (Continued)

Results for Vacuum Cleaning Followed by Sellers Cleaning

Surface Decontaminated	Activity before Decontamination (m μ c)	Activity after Decontamination (m μ c)	Contamination Remaining (per cent)
Shingles, Asbestos	4,450	435	10
	1,750	97	6
	450	97	21
	500	80	16
	550	80	15
	600	97	16
	350	80	23
	350	80	23
	550	97	18
	550	129	23
	650	161	25
	400	129	32
	450	113	25
	(mr/hr)	(mr/hr)	
Tar and Gravel	460	55	12
	460	23	5
	450	47	10
Drain Pipe	250	55	22
Roofing Paper	34	11	32
	41	10	24
	39	5	13

TABLE 6.6

Results for Vacuum Cleaning Followed by Fire Hosing

Surface Decontaminated	Activity before Decontamination (m μ c)	Activity after Decontamination (m μ c)	Contamination Remaining (per cent)
Paint, Navy 5H	4,300	491	11
	650(a)	382	59
	4,700	450	10

TABLE 6.6 (Continued)

Results for Vacuum Cleaning Followed by Fire Hosing

Surface Decontaminated	Activity before Decontamination (m μc)	Activity after Decontamination (m μc)	Contamination Remaining (per cent)
Paint, Army OD	9,500	831	9
	500[(a)]	354	7
	3,500	491	14
Paint, Zinc Chromate	8,000	1,159	14
	650[(a)]	627	96
	1,700	736	43
Strippable Coat	4,000	845	21
	3,300[(a)]	2,045	62
	4,500	1,362	30

(a) One measurement of the several between "before" and "after" is questioned (see Sec. 6.5).

6.4.2 Relative Effectiveness of Protective Coatings

The data on the relative effectiveness of protective coatings are given in Table 6.7 in terms of ranges of percentage contamination remaining after decontamination.

TABLE 6.7

Residual Contamination on Surface Coatings

Surface Coating	Contamination Remaining after:(a)				
	Fire Hosing (per cent)	Sellers Cleaning (per cent)	Vacuum Cleaning (per cent)	VC + FH (per cent)	VC + SC (per cent)
Painted, Navy 5H	45-73	9-19		10-59	1-20
Painted, Army OD	42-68	16-40	17-28	9-14	
Unpainted, Clean	29-36				
Weathered, Old Paint, Rust	8-61		32-65		
Tar and Gravel		9-15	22-45		5-12
Shingle, Asbestos			31-91		6-32
Strippable Coat	40-53		52-61	21-62	

(a)
VC + FH: Vacuuming followed by fire hosing.
VC + SC: Vacuuming followed by Sellers cleaning.

[redacted]

6.4.3 Time and Man Power Requirements

The data obtained on time and man power for the decontamination methods tested are tabulated in Table 6.8.

TABLE 6.8

Man Power Requirements

Surface	Base Surface	Men Required per Team	Unit Time (hr)	Surface Covered (sq ft)	Min Decon Obtainable (per cent)
		VACUUM			
Tar and Gravel	Plywood	2	1	150	70
Asbestos Shingles	—	2	1	350	40
Roofing Paper	—	2	1	350	40
Navy 5H	Plywood	2	1	350	80
Acrylic	Plywood	2	1	350	80
		FIRE HOSE			
Galvanized	Steel	4	1	6,000	60(a)
Navy 5H	Cor. Steel	4	1	6,000	40(a)
Army OD	Cor. Steel	4	1	6,000	40(a)
		SELLERS			
Tar and Gravel	Cor. Steel	3	1	900	90(a)
Navy 5H	Cor. Steel	3	1	1,400	70(a)
Navy 5H	Drop Siding	3	1	1,400	90(a)
Army OD	Cor. Steel	3	1	1,400	70(a)
Army OD	Drop Siding	3	1	1,400	90(a)
Navy 5H	Cor. Steel	3	1	1,000	80(b)
		VACUUM AND FIRE HOSE(c)			
Navy 5H	Cor. Steel	4	1	400	70(d)
Army OD	Cor. Steel	4	1	400	70(d)
		VACUUM AND SELLERS(c)			
Tar and Gravel	Plywood	4	1	200	80
Asbestos Shingles	—	4	1	450	80
Navy 5H	Plywood	4	1	450	90
Acrylic	Plywood	4	1	450	90
Roofing Paper	—	4	1	450	70

(a) Conducted in two cleaning passes with drying period between.

(b) In addition, scrubbed vigorously with window brushes.

(c) Using four men operating with vacuum cleaner having two outlets (two men per nozzle or outlet).

(d) Vacuumed with 15-in. rectangular brush and 3-in. circular brush. Fire hosing conducted in 2 passes; drying period between.

6.4.4 Additional Information

Data on air sampling are shown in Table 6.9. Data on sampling of liquid waste are tabulated in Table 6.10.

TABLE 6.9

Air Sampling Data[(a)]

			General Working Area		Immediate Test Vicinity		General Background 2,000-ft Upwind	
Type of Operation	Date of Operation	Sampler Location	Airborne Activity[(b)] (d/m/cu ft)	Collection Time (hr)	Airborne Activity[(b)] (d/m/cu ft)	Collection Time (hr)	Airborne Activity[(b)] (d/m/cu ft)	Collection Time (hr)
Vacuum Cleaning	6 Dec. (U + 7)	Upwind	3.8	5	17	50	2.15	5
Fire Hosing		Downwind	7.6	5	42.5	40		
1st Sellers Run	7 Dec. (U + 8)	Upwind	1.6	5	118	30		
2nd Sellers Run					51	30	0.63	5
Fire Hosing		Downwind	6.5	5	49	15		

(a) For description of air sampling apparatus, refer to Chapter 11.

(b) All activities listed are for beta-gamma measurements. In all cases, the amount of alpha material detected was less than 1 d/m for each sample collected.

TABLE 6.10

Liquid Sampling Data[(a)]

Sample[(b)]	Mass of Solid Residue (gm/100 cc)	Intensity of Solid Residue (μc/gm)	Concentration of Solid Residue (gm/gal)	Intensity of Solid Residue (μc/gal)	Intensity of Liquid Runoff (10^{-5} μc/cc)	Intensity of Liquid Runoff (μc/gal)	Intensity Ratio (solid/liquid)
S-1	0.47	4.4	18	79	690	26	3.0
2	0.30	2.5	11	29	470	18	1.6
3	0.33	3.0	13	37	550	21	1.8
4	0.82	1.4	31	43	150	5.7	7.6
5	1.2	2.5	45	110	12	0.46	240
6	1.3	2.2	48	107	11	0.42	250

TABLE 6.10 (Continued)

Liquid Sampling Data(a)

Sample(b)	Mass of Solid Residue (gm/100 cc)	Intensity of Solid Residue (μc/gm)	Concentration of Solid Residue (gm/gal)	Intensity of Solid Residue (μc/gal)	Intensity of Liquid Runoff (10^{-5} μc/cc)	Intensity of Liquid Runoff (μc/gal)	Intensity Ratio (solid/liquid)
S-11	0.16	4.7	6.1	29	44	1.7	17
12	0.16	3.4	6.1	21	48	1.8	11
13	0.21	4.6	8.0	37	30	1.1	32
14	0.29	2.0	11	21	17	0.64	33
15	0.39	3.3	15	48	27	1.0	48
						Average →	59
F- 1	2.0	3.7	75	280	77	2.9	95
2	2.1	22	77	1.700(c)	30	1.1(c)	1,500(c)
3	1.1	1.7	40	67	15	0.56	120
4	0.59	3.7	22	82	6.8	0.26	320
5	0.12	2.4	4.5	11	7.6	0.29	37
6	0.02	2.7	0.76	2.0	4.5	0.17	12
F-24	0.04	3.0	1.5	4.5	5.1	0.19	24
25	0.04	1.1	1.5	1.7	3.0	0.11	15
26	0.02	2.1	0.76	1.6	3.3	0.12	13
27	0.03	0.86	1.1	1.0	3.1	0.12	8.3
28	0.01	1.8	0.38	0.69	2.0	0.077	8.9
29	0.02	2.4	0.76	1.9	2.2	0.084	22
						Average →	61

(a) Approximate runoff rate for Sellers cleaning: 6 gal/min.
Approximate runoff rate for fire hose cleaning: 120 gal/min.

(b) S = Sellers cleaning. F = Fire hosing.

(c) These figures omitted in computing average of intensity ratios.

6.5 DISCUSSION OF RESULTS

6.5.1 Comparison of Methods

6.5.1.1 Fire Hosing and Sellers Cleaning

A comparison of Table 6.2 with Table 6.3 reveals that for similar surfaces such as painted corrugated steel, fire hosing was less effective than Sellers (hot liquid) cleaning. For example, on Army OD surface, after two fire hosing applications, contamination remaining was 42 to 68 per cent, whereas Sellers cleaning applied twice left only 16 to 40 per cent, if the single reading of 77 per cent is disregarded (Table 6.3).

However, this comparison should be qualified by the fact that field conditions favored Sellers over fire hosing. One of these field conditions was freezing weather, which, while hampering the effectiveness of both methods, hampered fire hosing more. During fire hosing operations, the average temperature of the water was about 32 deg F. (For Sellers cleaning, the average temperature was about 150 deg F.) In the fire hosing, on completion of a cleaning run, the remaining water on the shady side of Building 1 froze in a thin layer, preventing proper drainage. Thus, fire hosing may well be improved by the use of warmer water.[2] Another possible improvement is the use of wet mechanical scrubbing with brushes to precede warm-water fire hosing. In the field, no cleaning improvement by the use of scrubbing was noted.

Temperature conditions similar to those for fire hosing were experienced during Sellers cleaning, but the over-all decontamination by this method was improved by mechanical scrubbing with brushes and by the much warmer water supplied from the Sellers apparatus.

Laboratory tests support prewetting periods between liquid cleaning passes to improve over-all cleaning effectiveness. Nevertheless, while operating under freezing weather conditions, prewetting periods tended to depreciate the cleaning ability of the Sellers method. Each Sellers cleaning pass had to melt a thin sheet of ice and rewarm the surface. Under these circumstances, it would appear best to thoroughly clean a building by a progressive advance over surfaces in one set of cleaning passes without consideration of a prewetting period.

6.5.1.2 Vacuum Cleaning and Sellers Cleaning

A comparison of Table 6.3 with Table 6.4 indicates that for similar surfaces such as Navy 5H paint (over corrugated steel), vacuum cleaning was less effective than Sellers cleaning.

Nevertheless, one case arose where the decontamination effectiveness of the methods was less important than other demands of the decontamination task. This case was the cleaning of half of Building 3, the tar-and-gravel roof of which had a confining parapet making drainage a problem. Thus, while Sellers cleaning could decontaminate tar and gravel to a minimum of 5 per cent remaining activity, as compared with a minimum of 22 per cent for vacuum cleaning, the latter was more suitable on the roof surface.

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[2] Later tests at USNRDL have simulated field fire hosing conditions on field-contaminated plate samples. These tests indicated no significant improvement in cleaning with water at a temperature of at least 55 deg F.

But where drainage was not a problem, Sellers cleaning was particularly effective. Sellers cleaning is also especially effective in removing contaminant left after vacuum cleaning.

Most of the fall-out from the Underground Burst collected on horizontal surfaces, and very little on sheer vertical surfaces. Therefore, the amount of contaminant removed from a vertical surface by vacuum cleaning compared to the extensive effort involved suggests that other, more feasible decontamination methods should be used on vertical surfaces.

Extremely rough surfaces (tar and gravel or roofing felt) had very high initial levels. As the surfaces became less porous and rough and approached the smooth and impervious, the high initial levels decreased.

Of the major roofing materials used, the tar-and-gravel surface apparently collected and held large quantities of contaminant. And again, although high percentage decontamination can be obtained, high levels of activity remain as a reminder of the extreme porosity of tar-and-gravel surfaces. Much of the contaminant appears to be trapped with the gravel itself. Extensive removal of the gravel considerably decreases the percentage activity remaining.

Despite openings in all buildings, little contamination was observed on the interior wall surfaces.

6.5.1.3 Combination Methods

Vacuum cleaning, followed by Sellers cleaning, gave the best total decontamination, as indicated by results shown in Table 6.5. On Building 3, these two cleaning methods exerted complementary influences; vacuuming, although very slow, functioned well on the tar-and-gravel roof, while the Sellers cleaning functioned well on the walls.

As a combined operation, vacuuming before fire hosing did not give conclusive results (Table 6.6). Moreover, some discrepancies in measurements were noted.

6.5.2 Comparison of Surface Coatings

6.5.2.1 Decontaminability

There is no definite evidence that any particular spray coating, whether applied over metal or wood, possesses exceptional properties of decontaminability. Table 6.7 supports this opinion. The differences which occur in the percentage values of the table can be readily explained by the following factors:

1. The redistribution of contaminant after application of a cleaning method; i.e., higher radiation survey readings after first liquid cleaning application than before cleaning. (See footnotes of Tables 6.2, 6.3, 6.4, and 6.6.)

2. Surface configurations which minimize the effective application of a cleaning method; i.e., a corrugated surface tends to minimize the impact cleaning effects of liquid cleaning methods by deflecting the stream.

Although strippable coating is not a protective coating in the same sense as paint, Table 6.7 shows that the strippable coating[3] was approximately equal in decontaminability to the asbestos siding. During the freezing weather encountered in the test, the strippable coating could not be removed from the surface over which it was applied. (Although inconvenient, application of an outside source of heat will allow stripping.)

The term "unpainted surfaces" used in Table 6.7 signifies that no protective coating was applied specifically for this decontamination test. Actually, the "unpainted surfaces" were either somewhat deteriorated (rusty) galvanized steel or coated with an unidentified paint. With the exception of rusty surfaces, the decontaminability of "unpainted surfaces" was about equal to that of the spray coatings used.

A detailed study of the relative decontaminability of protective coatings applied to the three buildings is not within the scope of this report. A more complete series of clarification tests performed under better controlled field conditions is essential. Due to time limitations, the effect of weathering on the surfaces could not be investigated. No evaluation could be made of the effect of roughness and increased porosity produced by wind-blown sand deposited on both prime and finish spray coatings.

6.5.2.2 Contaminability

In general, horizontal surfaces collected and held more contaminant than sheer vertical surfaces. Surfaces oriented between these two extremes were contaminated more as the surfaces approached the horizontal.

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[3] Complete removal of strippable coating removes all activity on the surface protected.

Surface configurations which allowed collection of contamination were: bolts and nuts; foundation channels; joints in Buildings 1 and 2; and unsealed joints in Building 3.

6.5.2.3 Trends in Decontamination Studies

A study of the results shown in Tables 6.3 to 6.6 reveals a wide range of initial contamination on the three buildings. An equally wide spread of computed values is evident when the final levels after decontamination are expressed in percentage of contaminant remaining. Therefore, averaging these percentage figures for each surface has no real significance.

Invariably, low percentage remaining values are supported by high initial contamination; a progressive increase in percentage remaining is registered with correspondingly lower initial levels of contamination. From observations of a single cleaning pass for each individual decontamination method, there is some evidence that percentage remaining is an approximate inverse function of the initial level. This function can be expressed as:

$$\text{Percentage remaining} = \frac{\text{Constant}}{\text{Initial Level}} \times 100$$

Such a relationship between initial level and percentage remaining will show that it is increasingly difficult to remove contaminant deposited at successively lower initial levels. Finally, an initial level is reached where a single pass will remove none of the contaminant (100 per cent remaining), so that the initial level becomes the constant in the above equation. While this functional link is generally suggested by the data obtained, a series of future investigations must be formulated to establish conclusively this suspected mathematical dependency.

6.5.3 Discussion of Supplementary Data

6.5.3.1 Man Power Requirements

Field operations connected with these tests were performed under somewhat idealized conditions. A series of circumstances made it necessary to move the buildings to a relatively uncontaminated area. Nevertheless, the results obtained indicate that approximate man power requirements can be estimated for one story structures of similar configuration and size to those tested. To extrapolate the results to larger structures would introduce serious errors.

Basing a given cleaning process on the number of man-hours required to clean x sq ft of surface regardless of building size would lead to the belief that man power requirements could be estimated

[redacted]

by direct proportioning. Larger structures of several stories height would require more time to decontaminate, since moving equipment, setting up scaffolding or positioning devices, etc., would lengthen the total cleaning process. Thus, to conclude that a given cleaning process might be done in one-half or one-quarter the time by doubling or quadrupling man power is an error. Overuse of man power may actually cause interference of one group with another.

Consequently, estimates have been made on a team basis for the equipment and structures used. In Table 6.8, for each method, approximate man power requirements are listed for a team of x men to decontaminate a given surface configuration to x per cent of its initial level in one hour for x sq ft.

The use of existing equipment in connection with these tests indicates that sufficient man power was available to conduct all essential maneuvers. Undoubtedly, however, some redesign or more careful selection of components integrated into a compact unit would make for better application of man power.

6.5.3.2 Airborne Contamination Hazard

The air sampling data taken during building decontamination tests are not extensive due to the unique conditions under which sampling was undertaken; i.e., the contaminated buildings were removed from their original location to a relatively uncontaminated area. No evaluation of the hazard produced by operations in a contaminated area could be made, but it is probable that if airborne contaminant measurements had been taken under realistic conditions, a marked increase in activity levels would have been shown.

On the basis of Table 6.9 and of direct observation of field conditions, it is advisable to protect the decontamination teams with: full-face masks equipped with the Chemical Corps M-11 type canister; suitable clothing; and facilities for personnel decontamination.

6.5.3.3 Waste Disposal

Table 6.10 shows that for the liquid methods, the contaminant as solid material is dispersed fairly evenly throughout the solid residue (sand, etc.). The table also shows that about 98 per cent (average) of the contaminant is part of the solid residue and that 2 per cent remains in solution with the liquid waste.

Figure 6.5 shows the waste disposal system used in the tests. From the data of Table 6.10 and field observations, it appears sufficient to dig a sump at any location convenient for operations and to fill in the pit after the operation.

6.5.4 Field Notes and Observations

Field application of a decontamination method, or methods, must be based on an astute appraisal of existing conditions which are established by the operational variables found in Table 6.11.

TABLE 6.11

Variables Affecting Decontamination

Fire Hosing	Sellers Cleaning	Vacuum Cleaning
Water pressure, nozzle	Temperature of water leaving lance	Type nozzle
Water temperature, nozzle	Pressure of water leaving lance	Air flow rate
Air temperature	Type of nozzle attached to lance	Type and condition of surface
Wind direction	Air temperature	Type of contaminant adhering to surface
Angle of hose stream with respect to surface	Wind direction	Static suction pressure
Average rate quantity (volume per unit time) of water supplied per unit area of surface	Average rate quantity (volume per unit time) of water applied per unit area of surface	"Running" suction pressure
Type of fire nozzle	Angle of stream with respect to surface	Humidity and precipitation (meteorological conditions)
Type and condition of surface	Type and condition of surface	
Configuration and orientation of surface	Configuration and orientation of surface	
Distance of nozzle from surface	Type and concentration of detergent added to hot water stream leaving lance	
Type of contaminant adhering to surface	Distance of nozzle from surface	
Fresh- or salt-water application	Type of contaminant adhering to surface	
	Fresh- or salt-water application	

Some of the variables (for example, meteorological conditions) cannot be controlled but others can be controlled or stabilized (somewhat arbitrarily) in the field. Conditions complicating the control of the dependent variables were:

1. A limited water supply and transportation difficulties (3-hr round trip from working area) confined the fire hosing tests to two washings of one building. The single tank trailer available held approximately 3,000 gal of water, allowing 1,500 gal per washing. In order to allow a reasonable amount of time for maneuvering hose and nozzle into position and to set the surfaces, the P-500 pump was regulated to operate at about 60 psi for a delivery of 200 gal per min.

2. The steam generator available could not supply sufficient steam to operate the Sellers injector at rated capacity. Thus, lower water temperatures were accepted at the lance to allow proper steam-water ratios through the injector.

During the 1-hr interval after Surface Shot time on 19 November 1951, prevailing winds deposited contaminant having a radiation level of approximately 6 r/hr. This unforeseen circumstance necessitated revision of "cold run" and training plans. These revisions and explanatory reasons are listed as follows:

1. Limited the working and training time in the contaminated area around the buildings, a decision primarily enforced to conserve maximum personnel exposure intervals to all work after Underground Shot. An evaluation of team training therefore was not undertaken.

2. Motivated abandonment of field testing a nonradioactive simulant (fluorescent powder) to determine the feasibility of its use as a reliable substitute for dry-dispersed radioactivity. The performance of the simulant was to be based on work undertaken on noncontaminated building surfaces. No reasonably accurate prediction could be made as to a comparable performance over a mildly contaminated surface, hence, the decision to discard this objective from the tests.

On 29 November 1951, the contaminant dispersed by effects of the Underground Shot resulted in a radiation level of approximately 200 r/hr at 1 hr after shot time. Decontamination of buildings was to be conducted in a radiation field not to exceed 100 mr/hr, so that an interval of waiting before entering the area was anticipated to allow normal radioactive decay to reduce the radiation field to the preselected working value. This interval of delay interposed the hazard of weather changes which would influence the success of the selected methods of decontamination.

An extensive wind and rainstorm occurred during the night of 4-5 December and about 0.20 in. of rainfall washed considerable contaminant from the buildings. After having dried, the remaining contaminant could not be considered a counterpart of the original dry-dispersed radioactivity insofar as relative ease of removal from surfaces was concerned.

During the period 5 through 8 December from 6 through 9 days after Underground Shot, daytime air temperatures accompanied by brisk winds did not exceed 34 deg F, thereby placing constraining influences upon the activities of personnel and operation of equipment.

As a direct result of wind, a continuous re-scattering of contaminated dust was apparent. An unknown amount of this radioactive dust, therefore, was sporadically distributed to or from the building area, causing some doubt as to the expected radiation levels and anticipated entrance time into the area to perform decontamination operations. Furthermore, continual recontamination could reduce the accuracy of field decontamination data for each cleaning method. As a consequence of these adverse circumstances, the buildings were moved to a new location on the northwest missile strip.

6.6 CONCLUSIONS

6.6.1 Decontamination Methods

From the building decontamination tests, the following conclusions are drawn regarding the methods:

1. Vacuum cleaning followed by Sellers cleaning was the most effective decontamination method (85 per cent over-all decontamination when applied to painted wood and tar-and-gravel surfaces).

2. Wet, mechanical scrubbing was applicable in improving Sellers cleaning (14 per cent improvement per single cleaning pass). No similar conclusion was made for fire hosing.

6.6.2 Surface Coatings

The following conclusions pertain to types of surfaces:

1. No significant differences in contaminability or decontaminability could be observed between various protective coatings.

2. In general, composition roofing, roof paper (or felt), and asbestos siding had similar decontaminability properties when subjected to the combination method of vacuum + Sellers cleaning.

6.6.3 Supplementary Results

1. No significant health hazards were found which were attributable to decontamination operations.

2. The problem of liquid waste disposal was solved by channeling waste liquids to a sump dug in the ground.

3. Realistic man power requirements could not be extrapolated from these tests.

6.7 RECOMMENDATIONS

The following recommendations are offered:

1. Continue the investigation of building decontamination and further evaluate the effectiveness of the methods employed.

2. Continue research on instrumentation to provide reliability in high intensity gamma radiation fields.

3. Develop a vacuum cleaner having a greater capacity for intake air when operating against higher vacuums.

4. Design and develop protective clothing for use by decontamination personnel, with such factors as cold weather comfort to be considered.

5. Conduct advance training of personnel for greater efficiency during the actual operations.

6. In advance of any future tests, enable principal investigators to make adequate appraisals of the test site and attendant field conditions.

7. Provide accessible and ample field storage facilities, both outdoor and indoor, temporary and permanent. Arrange for an adequate water supply near the field test locations.

8. Consider procuring equipment that is a single, self-contained mobile unit designed for a specific decontamination operation. Such a unit would simplify transportation problems, and reduce time, hazards, and effort.

9. Redesign the M-11 Chemical Corps respirator to include either a mechanical or electronic communication device.

CHAPTER 7

DECONTAMINATION OF CONSTRUCTION MATERIALS

E. H. Dhein

7.1 INTRODUCTION

This chapter describes an investigation to determine the contamination-decontamination characteristics of typical construction materials that had been exposed to the effects of surface and underground atomic bomb detonations. Following contamination, the materials were subjected to vacuum cleaning and high pressure hosing, and the decontamination results were evaluated.

The test results described here, together with the findings of planned future investigations and related tests, will be used to establish protective criteria and standard operating procedures for the decontamination of military installations.

7.2 OBJECTIVES

The field test was undertaken:

1. To determine the contaminability of coated and uncoated surfaces of construction materials used by the U.S. Army Corps of Engineers, and thereby to establish and compare the merits of the various protective coatings employed.

2. To investigate protective measures other than coatings which might reduce contamination and/or facilitate decontamination.

3. To acquire practical knowledge on the distribution pattern of radioactive contaminants, including the effect of the slope of a surface on its contaminability.

4. To determine the relative effectiveness and operational feasibility of various decontamination methods.

7.3 PROCEDURE

7.3.1 Apparatus and Materials

The testing apparatus, in essence, consisted of forty-five 4- x 6-ft plywood panels, arranged as shown in Fig. 7.1 and located 7,060 ft from ground zero, north 41° east of Underground Shot. Erection was completed prior to the Surface Shot.

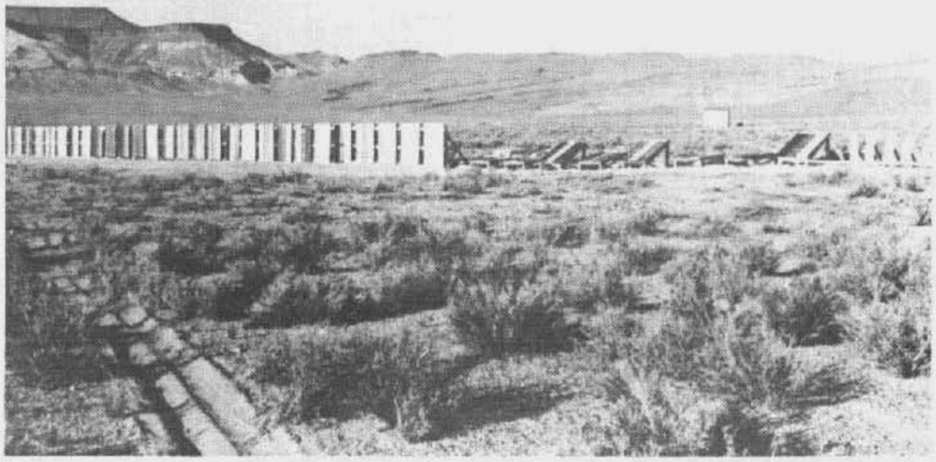


Fig. 7.1 Panel Layout

Panels exhibiting materials normally used for wall construction were mounted vertically and supported on a substantially built continuous "A" frame assembly (Fig. 7.2). Panels exhibiting materials used for roof surfaces were supported on independent frames aligned laterally with the vertical panel assembly and mounted on slopes representing their normal pitch; for example, built-up roofing panels were mounted on 3/4-in. pitch, smooth-surfaced roll roofing on 3-in. pitch and asphalt strip shingles on 6-in. pitch.

Mounted on 42 of the panels were the specimens of construction materials listed in Table 7.1, constituting a representative sample of the types of material encountered in military installations.

Mounted on each of the remaining three panels were a series of "geometry effects" sub-panels, each of which displayed a separate size and shape, or orientation (Fig. 7.3).

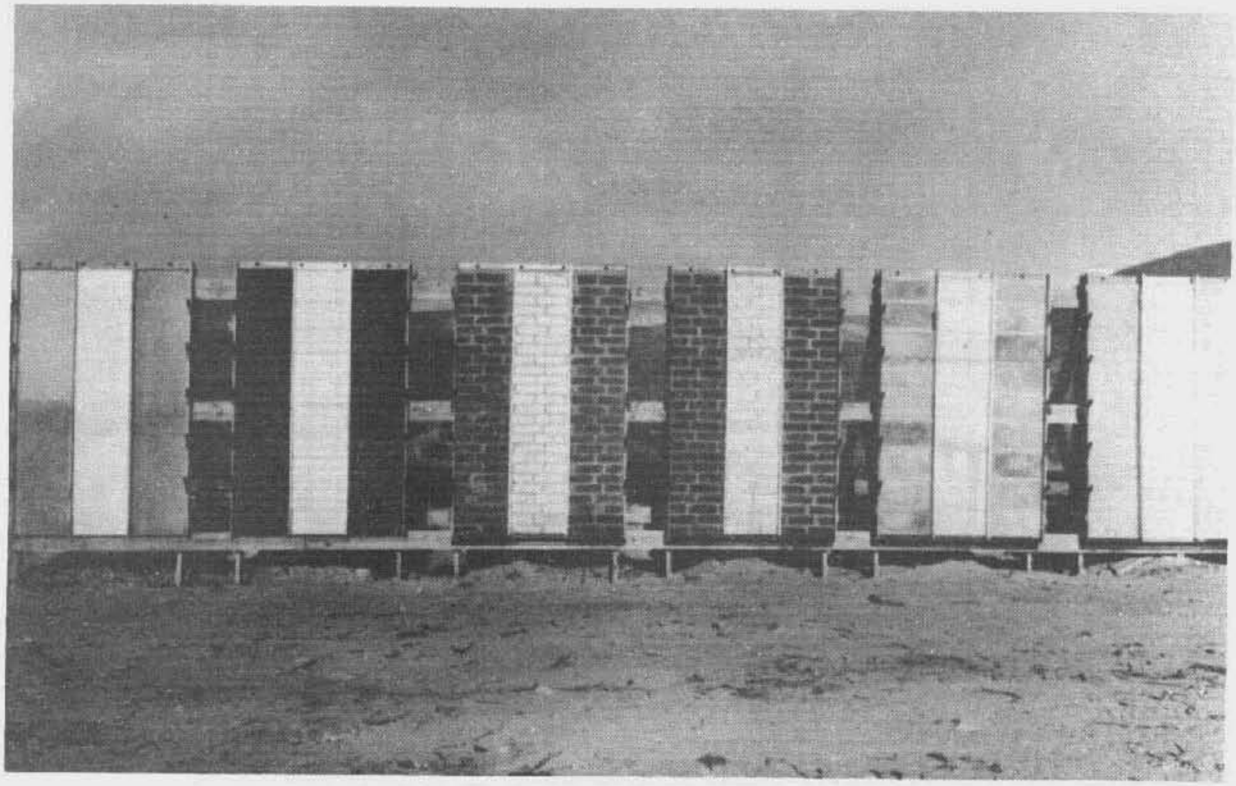


Fig. 7.2 Typical Experimental Panels

TABLE 7.1

Distribution of Protective Coatings

Base Materials	Panel No.	Protective Coatings(a) Primer	Intermediate	Finish
Asbestos Cement Sheets	2a			Untreated
	2b	None		Polyvinyl Alcohol P
	2c	None		Industrial Film, Syn.
Asbestos Cement Sheets	14a	No.1	No.4	Alkyd Enamel
	14b	None		Bakelite Resin
	14c	None		Cellulose Acetate
Asbestos Cement Sheets	15a	None		Lacquer, Clear
	15b	No.1	No.3	Lead and Oil Paint
	15c	No.1	No.2	Multiple Pigm. Paint

TABLE 7.1 (Continued)

Distribution of Protective Coatings

Base Materials	Panel No.	Protective Coatings(a)		
		Primer	Inter-mediate	Finish
Asbestos Cement Sheets	16a 16b 16c	No.1 None None		Phenolic Enamel Polyvinyl Alcohol, UP Resin, Emulsion, Ext.
Asbestos Cement Sheets	17a 17b 17c	No.1 None None		Resin, Natural (ACC) Silicone Resin Strippable, Pigm.
Asbestos Cement Shingles	3a 3b 3c	 None None		Untreated Polyvinyl Alcohol, P Industrial Film, Syn.
Brick, Low-density	4a 4b 4c	 None None		Untreated Polyvinyl Alcohol, P Industrial Film, Syn.
Brick, Low-density	18a 18b 18c	None None None		Bakelite Resin Camouflage Paint Cellulose Acetate
Brick, Low-density	19a 19b 19c	None No.1 None		Lacquer, Clear Resin, Natural (ACC) Silicone Resin
Brick, High-density	5a 5b 5c	 None None		Untreated Polyvinyl Alcohol, P Industrial Film, Syn.
Brick, High-density	20a 20b 20c	None None None		Bakelite Resin Camouflage Paint Cellulose Acetate
Brick, High-density	21a 21b 21c	None No.1 None		Lacquer, Clear Resin, Natural (ACC) Silicone Resin
Concrete Block	6a 6b 6c	 None None		Untreated Polyvinyl Alcohol, P Industrial Film, Syn.

TABLE 7.1 (Continued)

Distribution of Protective Coatings

	Panel No.	Protective Coatings(a)		
Base Materials		Primer	Intermediate	Finish
Concrete Block	22a 22b 22c	None None None		Lacquer, Clear Resin Emulsion, Ext. Strippable Pigm.
Concrete, Rough Form	7a 7b 7c	 None None		Untreated Polyvinyl Alcohol, P Industrial Film, Syn.
Concrete, Rough Form	23a 23b 23c	None None None		Camouflage Paint Cellulose Acetate Lacquer, Clear
Concrete, Rough Form	24a 24b 24c	None No.1 None		Polyvinyl Alcohol, UP Resin, Natural (ACC) Strippable Pigm.
Concrete, Smooth Form	8a 8b 8c	 None None		Untreated Polyvinyl Alcohol, P Industrial Film, Syn.
Concrete, Smooth Form	25a 25b 25c	None None None		Camouflage Paint Cellulose Acetate Lacquer, Clear
Concrete, Smooth Form	26a 26b 26c	None No.1 None		Polyvinyl Alcohol, UP Resin, Natural (ACC) Strippable, Pigm.
Felt and Batten Siding	9a 9b 9c	 No.5 None		Untreated Polyvinyl Alcohol, P Industrial Film, Syn.
Felt and Batten Siding	27a 27b 27c	None None None		Bakelite Resin Resin Emulsion, Ext. Resin, Natural (ACC)
Metal, Galv. Corrugated	10a 10b 10c	 No.5 None		Untreated Phenolic Enamel Bakelite Resin

TABLE 7.1 (Continued)

Distribution of Protective Coatings

Base Materials	Panel No.	Protective Coatings(a)		
		Primer	Intermediate	Finish
Metal, Galv. Sheet	11a			Untreated
	11b	No.6		Polyvinyl Alcohol, P
	11c	None		Lead and Oil Paint
Siding, Wood	13a			Untreated
	13b	None		Polyvinyl Alcohol, P
	13c	None		Industrial Film, Syn.
Siding, Wood	31a	No.4		Alkyd Enamel
	31b	None		Bakelite Resin
	31c	None		Camouflage Paint
Siding, Wood	32a	None		Cellulose Acetate
	32b	No.8	No.3	Lead and Oil Paint
	32c	No.2		Multiple Pigm. Paint
Siding, Wood	33a	No.4		Phenolic Enamel
	33b	None		Polyvinyl Alcohol, UP
	33c	None		Resin Emulsion, Ext.
Siding, Wood	34a	None		Resin, Natural (ACC)
	34b	None		Silicone Resin
	34c	None		Strippable, Pigm.
Geometry Effects	35a	No.2		Multiple Pigm. Paint
	35b	No.2		Multiple Pigm. Paint
	35c	No.2		Multiple Pigm. Paint
Geometry Effects	36a	No.2		Strippable, Pigm.
	36b	No.2		Strippable, Pigm.
	36c	No.2		Strippable, Pigm.
Geometry Effects	37a	No.2		Multiple Pigm. Paint
	37b	No.2		Multiple Pigm. Paint
	37c	No.2		Multiple Pigm. Paint
Metal, Galv. Sheet	29a	No.6		Alkyd Enamel
	29b	None		Lacquer, Clear
	29c	None		Resin, Natural (ACC)

TABLE 7.1 (Continued)

Distribution of Protective Coatings

Base Materials	Panel No.	Protective Coatings(a) Primer	Inter-mediate	Finish
Metal, Steel Sheet	12a			Untreated
	12b	No.5		Polyvinyl Alcohol, P
	12c	No.7		Industrial Film, Syn.
Metal, Steel Sheet	30a	No.7		Camouflage Paint
	30b	No.7		Cellulose Acetate
	30c	No.7		Multiple Pigm. Paint
Roofing, Built-up, Asphalt	38a			Untreated
	38b	No.5		Polyvinyl Alcohol, P
	38c	None		Industrial Film, Syn.
Roofing, Built-up, Asphalt	43a	No.5		Cellulose Acetate
	43b	None		Resin, Natural (ACC)
	43c	None		Strippable, Pigm.
Roofing, Built-up, Tar	39a			Untreated
	39b	No.5		Polyvinyl Alcohol, P
	39c	None		Industrial Film, Syn.
Roofing, Built-up, Tar	44a	No.5		Cellulose Acetate
	44b	None		Lacquer, Clear
	44c	None		Phenolic Enamel
Roofing, Asphalt Shingles	40a			Untreated
	40b	No.5		Polyvinyl Alcohol, P
	40c	None		Industrial Film, Syn.
Roofing, Asphalt Shingles	45a	None		Lacquer, Clear
	45b	None		Resin, Natural (ACC)
	45c	No.5		Strippable, Pigm.
Roofing, Roll Type, Small	41a			Untreated
	41b	No.5		Polyvinyl Alcohol, P
	41c	None		Industrial Film, Syn.
Roofing, Roll Type, Small	1a			Untreated
	1b	No.5		Polyvinyl Alcohol, P
	1c	None		Industrial Film, Syn.

[redacted]

TABLE 7.1 (Continued)

Distribution of Protective Coatings

Base Materials	Panel No.	Protective Coatings(a) Primer	Intermediate	Finish
Roofing, Wood Shingles	42a			Untreated
	42b	None		Polyvinyl Alcohol, P
	42c	None		Industrial Film, Syn.

(a) Description of primer, intermediate, and final coats are available at CRL, Army Chemical Center, Maryland.

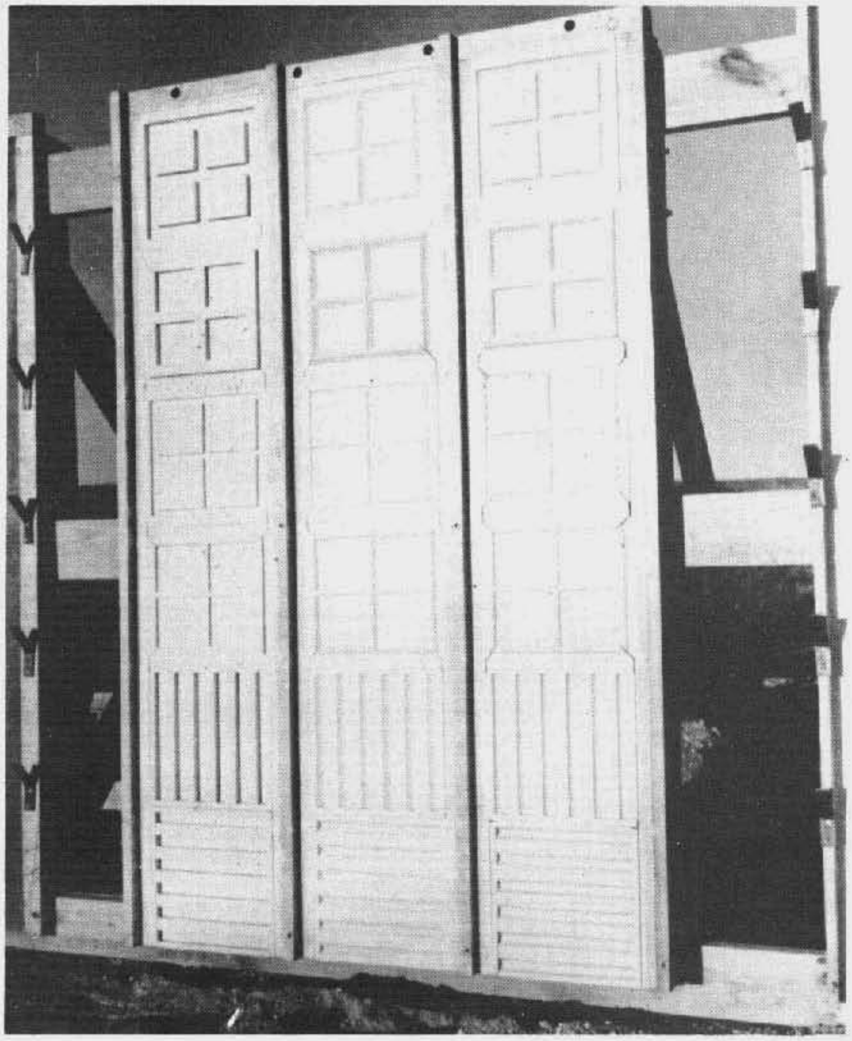


Fig. 7.3 Geometry Effects Panel

Each test panel was subdivided into three parts, separated by baffle strips 1 in. wide. One sub-panel, of each type of construction material, was left untreated for control purposes, but the remainder were coated with protective formulations as indicated in Table 7.1. The details on the protective coating formulations used in this test are available.

After the surface burst, a supplemental series of 10 small scale panels (1 x 3 ft) were constructed, coated, and erected prior to the Underground Shot (Fig. 7.4). These panels were positioned with slopes ranging from horizontal to vertical, in increments of 10°. One-half of each panel was coated lightly with diesel oil to facilitate capture and retention of the contaminant.

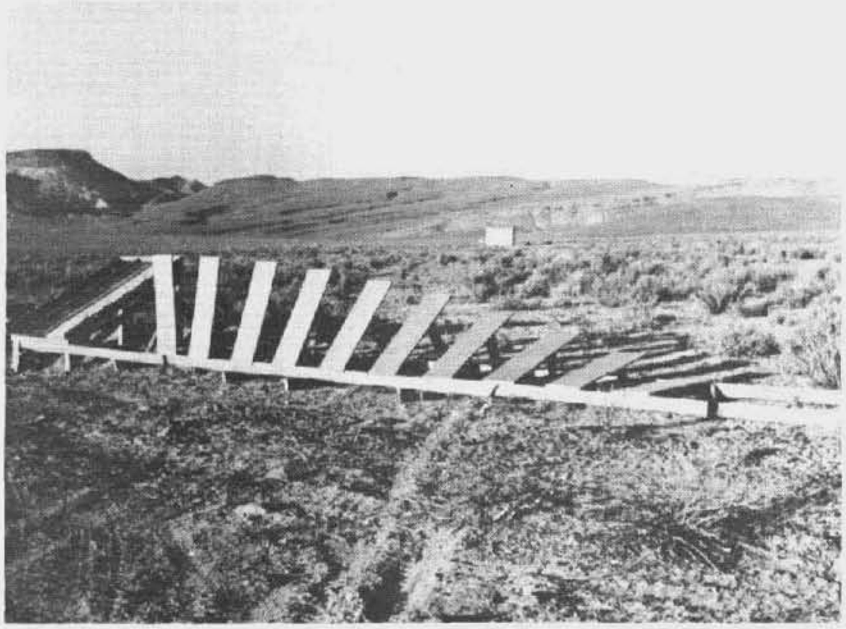


Fig. 7.4 The Fan Panel Assembly

To ascertain the value of removable-type protective covers for equipment, furnishings, and similar items in the interior of such structures as machine shops, communication centers, and laboratories, sheets of rubber hydrochloride film (approximately 4 mils thick) and strippable vinyl coating (approximately 14 mils thick) were applied to several spare panels prior to the Underground Shot.

7.3.2 Decontamination of Construction Materials

The components of the panels were decontaminated in two steps:

1. The lower section of each panel was vacuum cleaned by means of a commercial gasoline-powered vacuum cleaner (Spencer Turbine Co.).

2. The entire panel was then hosed, using the M3A1 Power Driven Decontamination Apparatus. A detergent (1 per cent Tide) was added to the water.

Original and residual contamination levels were determined quantitatively by beta measurements at each step.

7.4 TEST RESULTS

Table 7.2 indicates the activity levels of the protective-coated wall panels.

TABLE 7.2

Average Activity on Protected Walls

Protective Coating on Roof Materials	Microcuries per 100 sq cm
Polyvinyl Alcohol, Pigmented	0.02
Alkyd, Enamel	0.02
Resin, Natural (ACC)	0.02
Phenolic Enamel	0.03
Polyvinyl Alcohol, Unpigmented	0.03
Milti-pigment Paint	0.04
Lacquer, Clear	0.04
Resin, Emulsion, External	0.04
Strippable Film, Pigment	0.04
Industrial Film	0.04
Cellulose Acetate	0.04
Camouflage Paint	0.04
Bakelite Resin	0.05
Lead and Oil Paint	0.06
Control	0.07
Silicone Resin	0.07

Table 7.3 indicates the initial activity levels and the residual contamination after each decontamination procedure on roofing materials and their associated coatings.

TABLE 7.3

Average Activity on Roof Surfaces

Roof Surface	Contamination (Microcuries per 100 sq cm) Prior to Decontamination	Following Vacuuming	Following High Pressure Hosing
Protected			
Phenatic Enamel	8.3	4.3	0.2
Cellulose Acetate	10.2	3.8	0.3
Polyvinyl, Pigmented	10.4	1.6	0.2
Resin, Natural (ACC)	11.5	4.8	0.3
Lacquer, Clear	12.0	5.5	0.2
Strippable Film	12.2	10.2	0.3
Industrial Film	14.2	3.8	0.2
Unprotected			
Roofing, Tar	9.9	2.6	0.3
Roofing, Asphalt	10.6	3.2	0.2
Shingles, Asphalt	15.1	8.9	0.3
Shingles, Wood	16.1	4.5	0.4
Roofing, Roll	17.8	4.9	0.1

Figure 7.5 indicates the effect of pitch and oiled surface on the level of contamination and decontamination observed on the fan-panel assembly.

Figure 7.6 is an autoradiograph which indicates the effect of geometrical patterns on contaminant distribution.

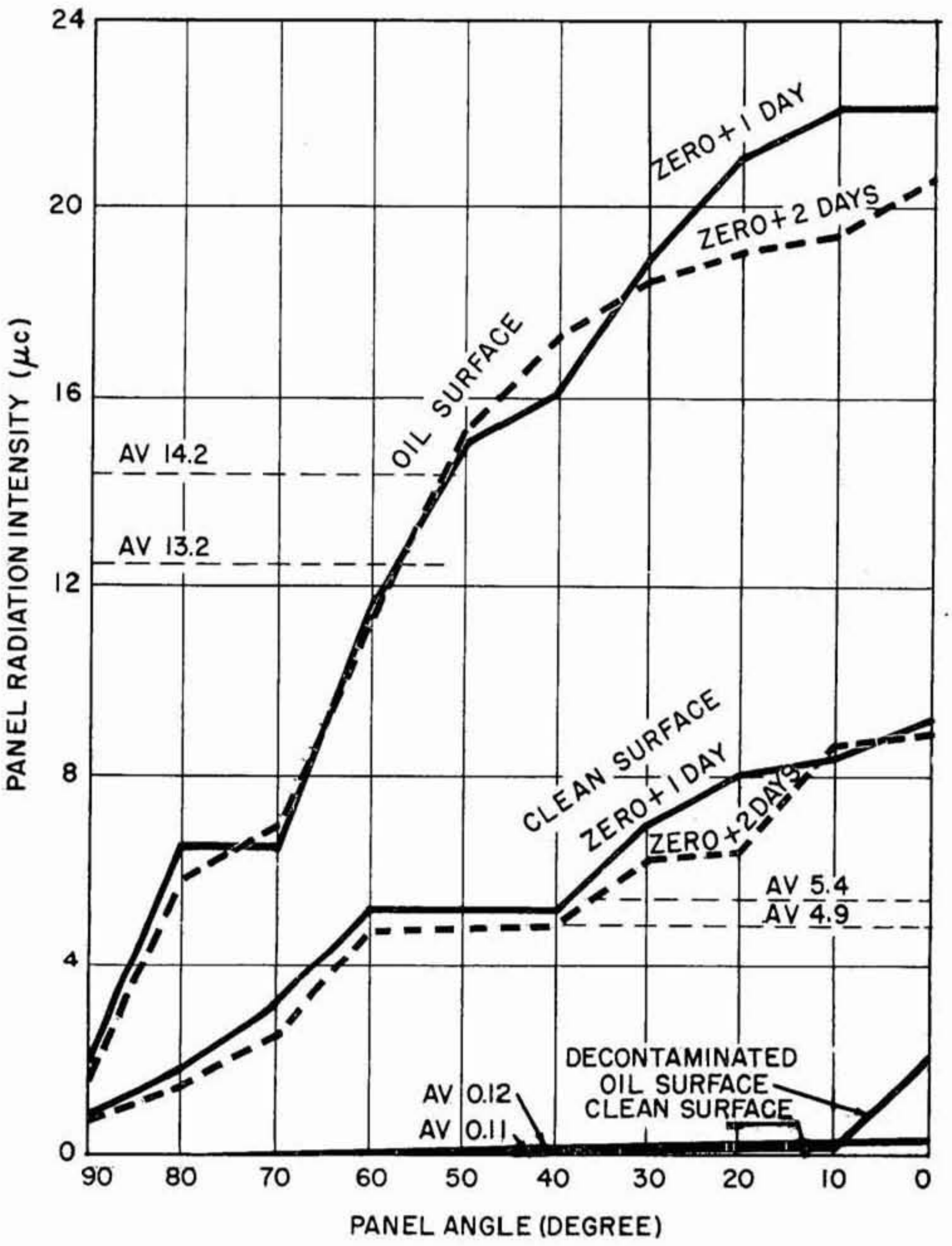


Fig. 7.5 Contamination-decontamination of Fan Panel Assembly

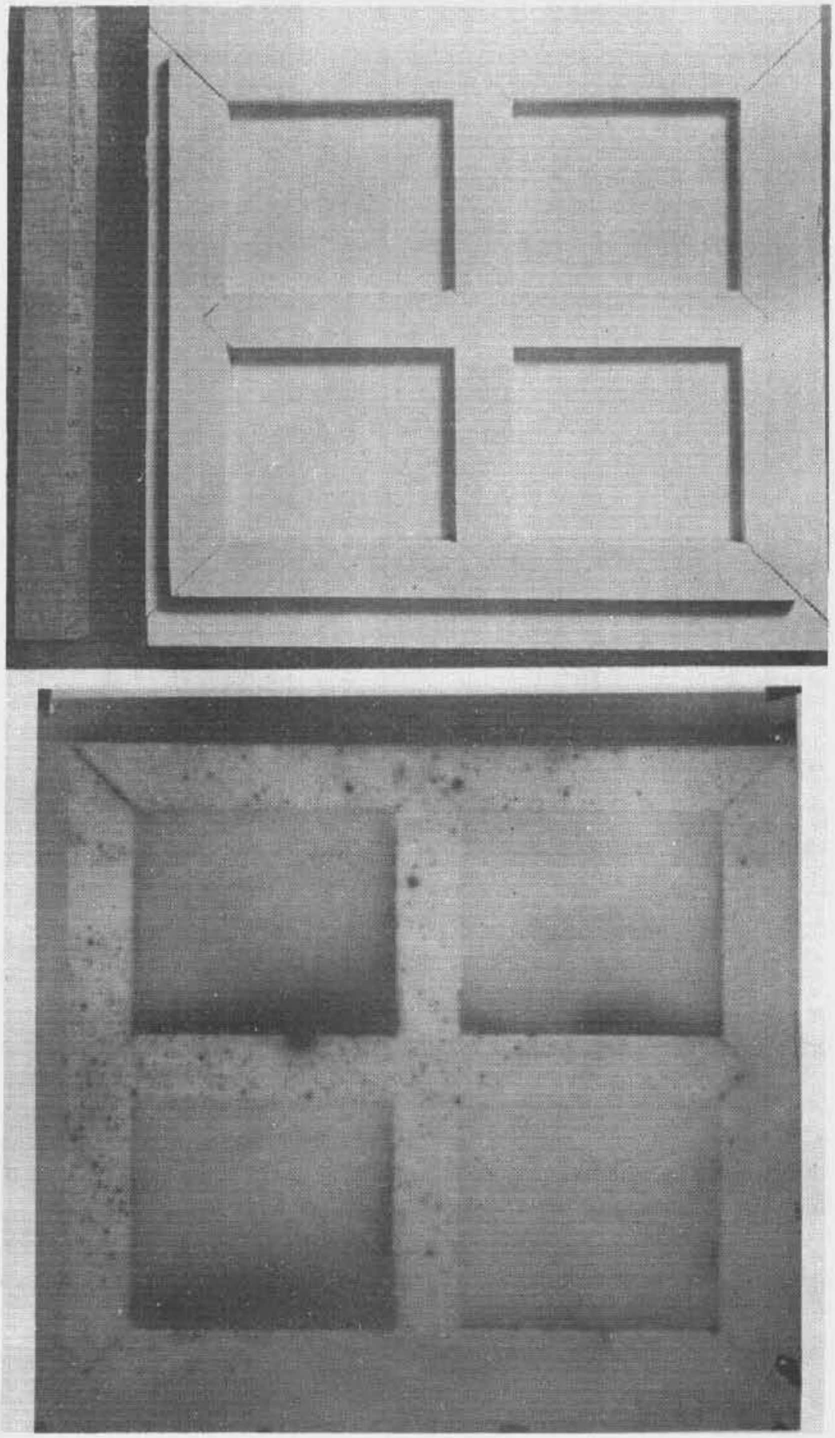


Fig. 7.6 Photograph and Autoradiograph of Geometry Effects Panel

7.5 DISCUSSION

The results of this test must be accepted with a considerable degree of caution insofar as generalized predictions are concerned. Results obtained were specific for the nature and circumstances of the test. No effort is made in this report to evaluate the effects of bomb energy, depth of burst, soil chemistry, particle size, and compaction of the soil, topography, and meteorological conditions on test results. Some of these parameters certainly had great bearing on the results. Further study is required before extrapolation can be safely attempted.

7.5.1 General: Surface and Underground Shots

A fairly extensive fall-out occurred unexpectedly, following the Surface Shot, in the vicinity of the test-panel site. Rain, snow, and high winds removed a considerable amount of contaminant from the test panels so that quantitative decontamination studies could not be made.

The major path of the contaminant fall-out following the Underground Shot bypassed the construction panel site. Nevertheless, full sets of readings were taken prior to and following decontamination. The following section concerns results from the Underground Shot studies.

7.5.2 Contamination Phenomena

7.5.2.1 Removable-type Protective Covers

Both the plastic film and the strippable coating were liberally contaminated. They inhibited completely the contamination of the underlying surfaces.

7.5.2.2 Oiled Surfaces vs Dry Surfaces, Coated Surfaces

The contamination retained by oiled surfaces was greater than twice that held by dry, clean, coated surfaces. The large initial retentivity of particles on oily surfaces tends to reduce materially the migration of contaminants, thus decreasing the airborne hazard. However, retention of contaminant on oiled surfaces increases external radiation hazard to contamination crews. The airborne hazard can be controlled by use of protective equipment, such as gas masks, but an external radiation hazard is difficult to control. This type of hazard is to be avoided if at all feasible.

7.5.2.3 Vertical vs Sloped Surfaces

The contamination retained by roof panels was approximately 300 times that held by the vertical panels. Due to the low level of contamination in this test, decontamination of walls was not required; however, this would not necessarily be true for a higher level of contamination.

7.5.2.4 Geometric Configurations

The autoradiograph (Fig. 7.6) indicates that angular shapes retained a higher concentration of contaminant than curvilinear projections and recesses. However, because of the low order of actual activity on the panels, further study of this phenomenon will be necessary before generalized conclusions can be stated.

7.5.2.5 Indication of Remigration

It will be noted that the readings for 1 day and 2 days after the Underground Shot (Fig. 7.5) do not conform to the fission-product decay law, which applied generally for the periods under discussion. It is believed that this deviation was caused by the rather extensive remigration of contaminant dust which followed the contaminating event.

7.5.3 Decontamination Phenomena

Because of the limited activity in the panel area, the decontamination effort was limited to vacuuming and high pressure hosing with detergent solution.

7.5.3.1 Vacuum Technique vs High Pressure Hosing

Decontamination by vacuuming was relatively ineffective. Vacuuming, at a decontamination rate of 40 sq ft per equipment hr left a high residual contamination, ranging from 9 to 84 per cent. A high pressure water stream with detergent additive, on the other hand, decontaminated a rough roof surface, slag- or gravel-finished, at a rate of approximately 600 sq ft per equipment hr and left an average residual contamination of less than 2 per cent. The Chemical Corps'Decontamination Apparatus, M3A1, was used in the present test and proved to be very satisfactory although solution capacity is limited. Areas located at a distance from the water supply can be decontaminated by using this apparatus. Where adjacent water supply is available, the use of a fire hose would give faster decontamination.

7.5.3.2 Oiled Surfaces

Oiled surfaces, though initially contaminated to a higher level, respond as readily as non-oily coated surfaces to decontamination by hosing with detergent solution.

7.5.3.3 Geometric Configurations

A normal washing operation, provided the pressure is high enough, removes a high percentage of contaminant from geometric configurations. However, the deeper the recess, the greater will be the amount of residual contamination, particularly where surface drainage is poor.

7.6 CONCLUSIONS

The following is a summary of the conclusions made from observations and test data.

1. From the standpoint of dry contamination, smoothness, hardness, and continuity of surface were parameters governing the contaminability-decontaminability characteristics of construction materials and protective coatings. The specific formulation of a protective coating, except as it affects the parameters indicated, appeared to be relatively unimportant.

2. Contamination found on walls was very small compared with that on roof surfaces; thus, decontamination of walls was relatively unimportant in this test. This would not necessarily be true if the level of contamination were greater. A subsidiary conclusion is that protective measures which would render roofs less contaminable, or facilitate their decontamination, might be of some value.

3. The degree of contamination appeared to vary directly with the slope of the surface from horizontal to vertical.

4. The application of an oil-like film over a surface prior to a contaminating event tended to increase the initial level of contamination and did not facilitate decontamination. Further exploration in this field, particularly on an operational scale does not appear to be justified.

5. Vacuuming was a relatively ineffective decontamination process, whereas, high pressure hosing using a detergent additive in water was very effective, and operationally feasible. (Subsequent experiments indicate that the detergent additive is advantageous only if an oil film is present.)

From test results, it is evident that the contamination of the land target complex resulting from surface and underground bursts constitutes a real and serious hazard and that further studies in this field are essential if appropriate protective and rehabilitative criteria are to be formulated. Sufficient data were accumulated on JANGLE to indicate the general trend of the contaminating event insofar as materials are concerned, but to be of maximum practical value, such data must be made available in terms of structures and aggregations of structures.

CHAPTER 8

CONTAMINATION-DECONTAMINATION PHENOMENOLOGY

L. B. Werner

8.1 ABSTRACT

Six experiments on contamination-decontamination phenomenology in both the Surface and Underground Shots at Operation JANGLE were designed to yield information on the following points:

1. The influence of the structural orientation of a surface on its contaminability.

2. The influence of the structural orientation of a surface on the particle size distribution of the deposited contaminant.

3. The influence of surface roughness and hardness on the contamination-decontamination behavior of materials.

4. The influence of surface cleanliness on the contamination-decontamination behavior of materials.

5. The contamination-decontamination behavior of selected commercially available materials exposed to solid particulate contaminants.

6. The effectiveness of selected chemical decontaminating agents on solid particulate contaminants.

The findings, considered to be specific for the conditions at the Nevada Test Site, were as follows:

1. Contamination on horizontal surfaces was frequently greater than that on non-horizontal surfaces. Differences of a factor of 30 to 40 were observed.

2. Vertical surfaces retained smaller particle sizes than inclined or horizontal surfaces.

3. Surface roughness had no clearly defined effect on contaminability. Surface roughness did affect decontaminability by factors of 6 to 10 (residual activity), the rough surfaces retaining more contamination than the smooth.

4. Deliberately soiled surfaces were more contaminable than clean surfaces by factors of 2 to 7.5, but decontaminated as well as or better than clean surfaces.

5. Navy gray paint was from 1.5 to 12 times as contaminable as bare aluminum, glass, and chromium-nickel steel, but all of these materials decontaminated readily.

6. The use of chemical additives was definitely advantageous in the immersion techniques employed for decontamination.

8.2 OBJECTIVES

The experiments reported here were designed to achieve the following three general objectives:

1. To provide information leading to the development of more efficient decontamination procedures in the field.

2. To provide information leading to the selection or development of materials having low contaminabilities and good decontaminability properties.

3. To provide information leading to the development of suitable design criteria (from a radiological standpoint) for military equipment and construction.

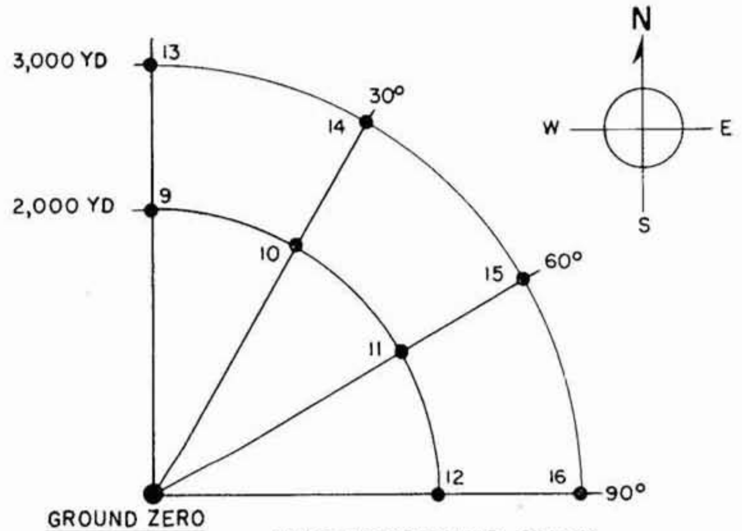
8.3 GENERAL EXPERIMENTAL PROCEDURES

Eight stations were used to expose samples at both detonations. The station pattern employed in each detonation is depicted in Fig. 8.1.

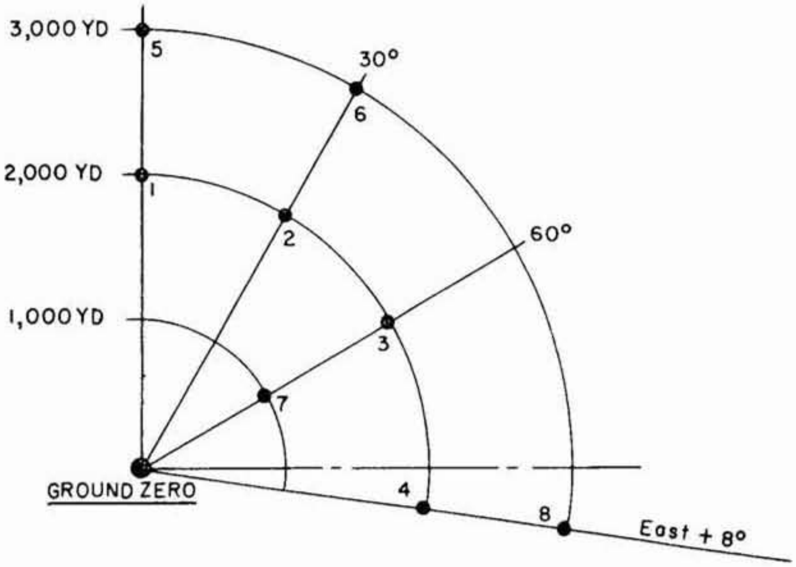
Samples were placed in exposure containers, and the containers, in turn, bolted to the top of plywood platforms. To minimize contamination of experimental material by dirt in the immediate vicinity of the stations, the 3/4-in. platform tops were fixed to steel legs which extended 4 ft above the ground.

The containers were constructed to expose materials for only a short time after detonation, and thereby protect samples against rain and prior soil deposition. The majority of the specimens were placed in "sliding tray" exposure containers as shown in Fig. 8.2.

Two triggers on each container controlled the opening and closing of the individual trays. All triggers were activated by a common mechanism which, in essence, consisted of preset rat traps operated by alarm clocks. The clocks were set to activate the springs of the rat traps at given time intervals before and after each detonation. The exposure container is shown in Fig. 8.3.



UNDERGROUND SHOT



SURFACE SHOT

Fig. 8.1 Exposure Station Patterns

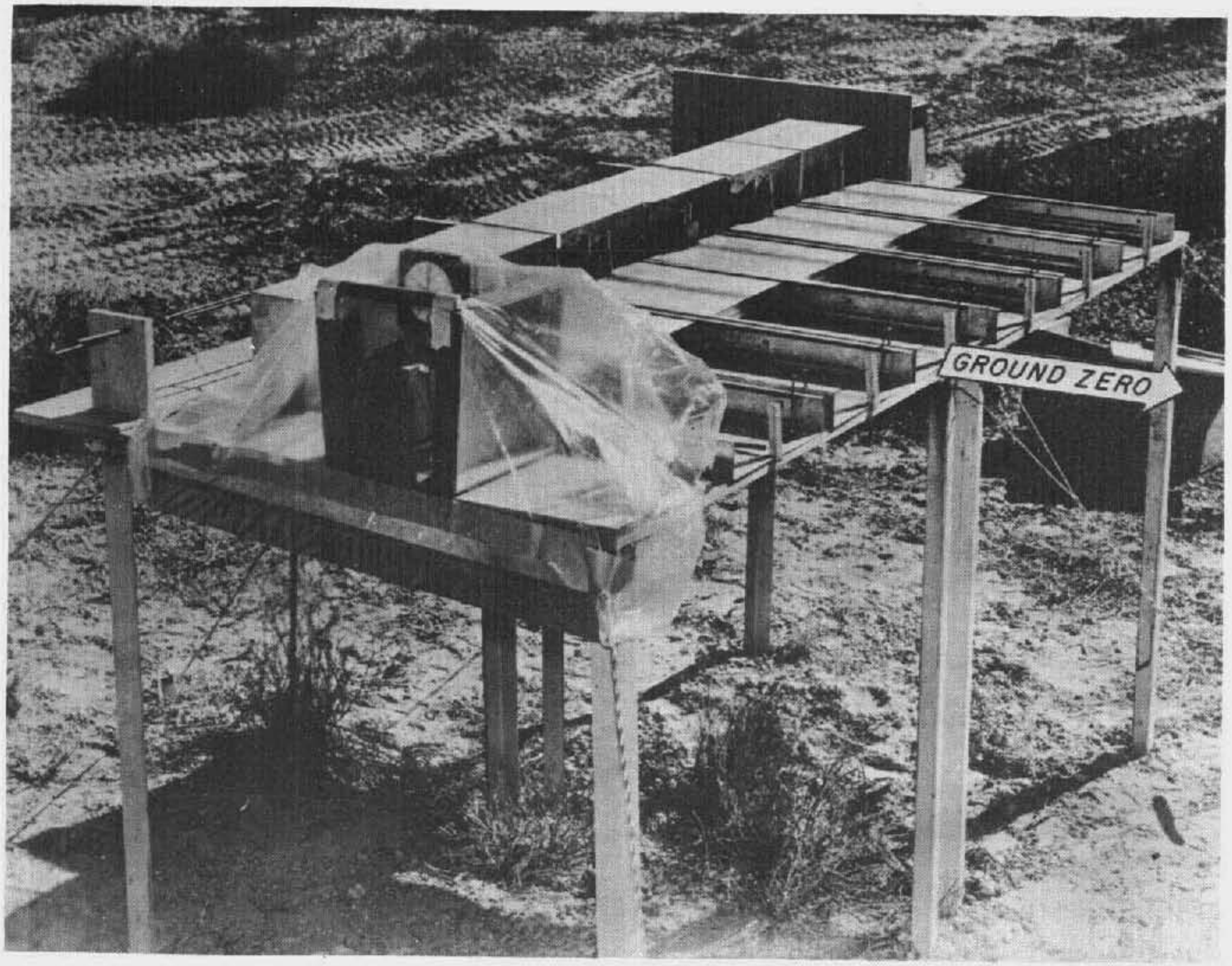


Fig. 8.2 Experimental Materials on Exposure Platforms

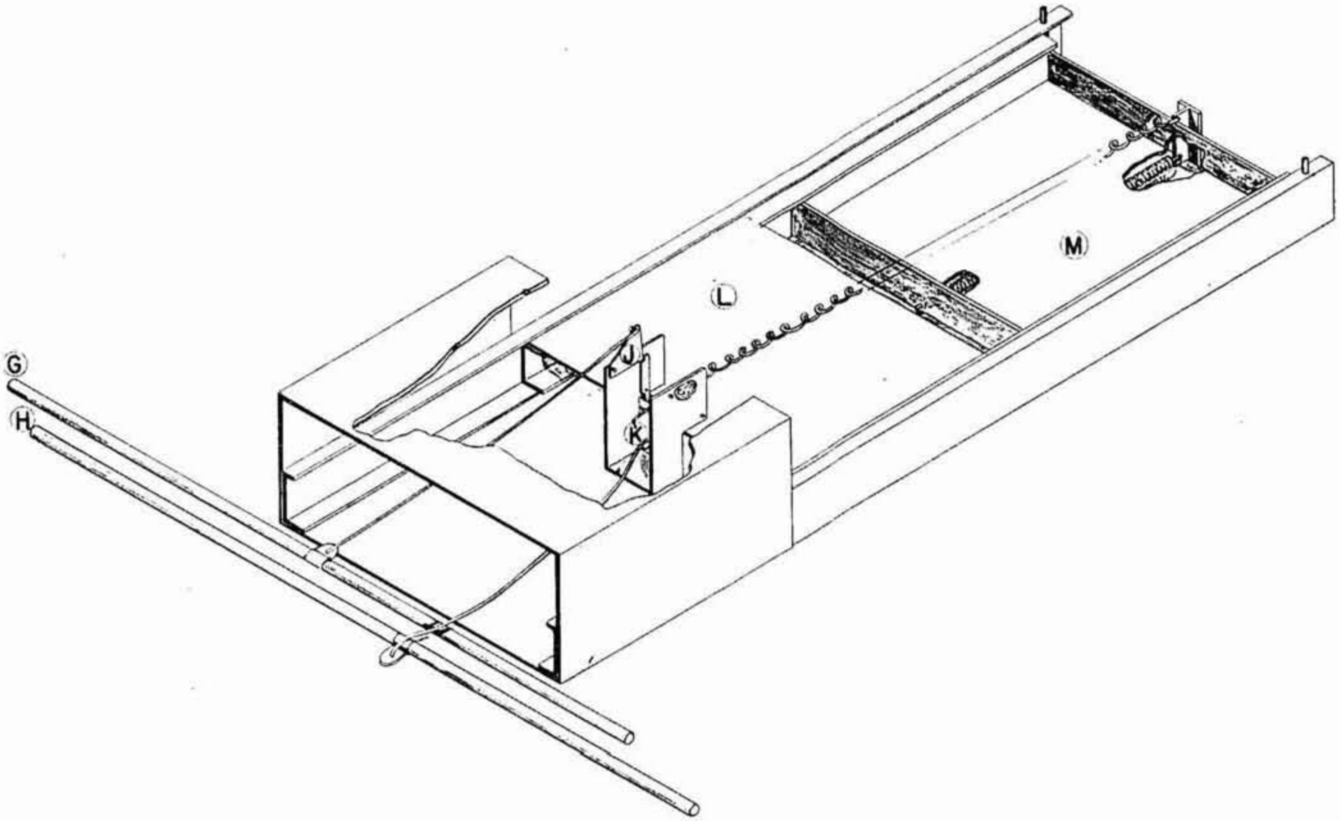


Fig. 8.3 Sliding Tray Apparatus

Legend

G—Shaft to release lid for post exposure protection of samples.
H—Shaft moving pan to sample exposure position.
J—Shear trigger to release lid.
K—Shear trigger to release pan.
L—Spring loaded lid to protect samples before and after exposure.
M—Spring loaded pan for sample exposure.

In recovering samples, trays and tray covers were removed as a unit, taped together, and transported to a building at a control point. At the control point, specimen panels were removed from the trays, individually covered, and placed in plastic bags before being crated for shipment to USNRDL.

All sample panels recovered after the Surface Shot were wet to varying degrees by heavy rains that had entered the exposure trays through two small openings in the lids; Underground Shot sample panels were not wetted. It is felt that since the experimental materials were returned to USNRDL via truck and subjected to jarring, contaminant redistribution occurred on some samples. This is felt to be particularly true in certain instances of heavy material deposition which occurred after the Underground Shot.

An outline of the main features of each of the six experiments is included in Figs. 8.4 through 8.9.

8.4 RESULTS AND DISCUSSION

The detailed results and discussion of the separate studies are reported in Secs. 8.4.1 through 8.4.6.

It is believed that the results obtained are specific for type of contaminating event and contaminant studied, viz. surface or underground atomic bomb detonation in sandy soil, and solid particulate contaminant.

8.4.1 Contaminability Characteristics of Materials as Determined by Their Orientation during and after Contamination

The results of this investigation indicate that the structural orientation of a surface does influence, to varying degrees, surface contaminability. This, of course, was determined only for the conditions of the JANGLE Underground Shot experiment; however, similar results were obtained at Operation GREENHOUSE.[1] The conclusions of Secs. 8.4.2 and 8.4.5 of this report also tend to support this thesis of orientation influence.

Comparisons were made between horizontal surface contamination and non-horizontal surface contamination. These evaluations have been included as Tables 8.1 and 8.2.

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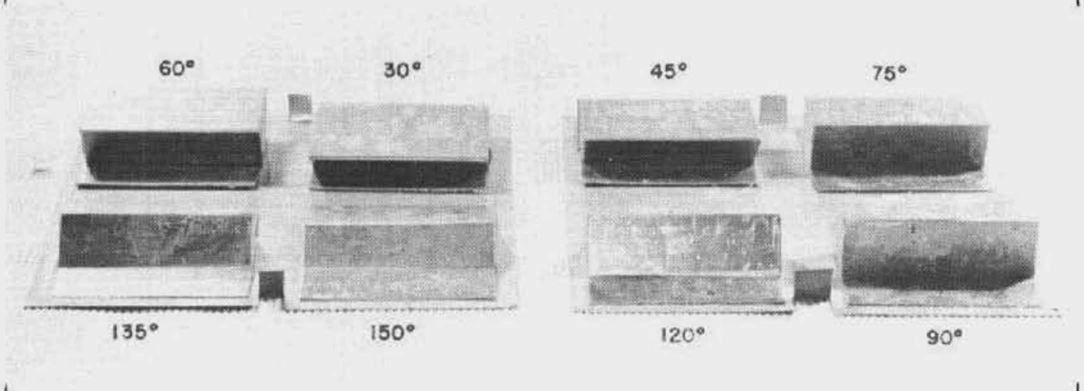
[1] L. B. Werner and S. Sinnreich, "Contamination-decontamination Studies", Operation GREENHOUSE, Project 6.7, Final Report, Sec. 3.1.1.2.



Purpose:

To determine the influence of the structural orientation of a material on the contaminability of the material.

Procedure:

Eight aluminum-faced wooden forms of the orientation angles shown above were exposed in sliding trays at each of eight stations. Aluminum faces were covered with cellulose acetate tape (adhesive side down). After exposure, the tapes were sprayed with plastic to fix the contaminant in place, stripped from the forms, and mounted flat on cardboard backing.

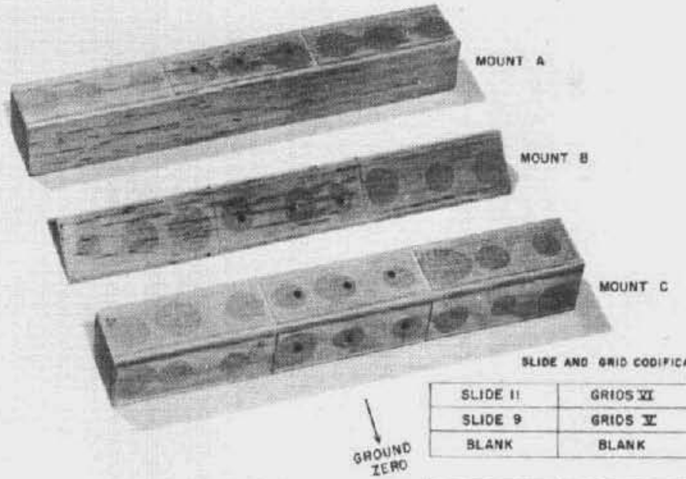
Data Taken:

Autoradiograph of each tape, and activity count of representative 1-in.-sq samples of each tape.

Results and Discussion:

See Sec. 8.4.1.

Fig. 8.4 Influence of Structural Orientation on Contaminability



SLIDE AND GRID CODIFICATION

SLIDE 11	GRIDS VI	SLIDE 12	MOUNT A
SLIDE 9	GRIDS V	SLIDE 10	
BLANK	BLANK	BLANK	
SLIDE 7	GRIDS IV	SLIDE 8	MOUNT B
SLIDE 5	GRIDS III	SLIDE 6	
BLANK	BLANK	BLANK	MOUNT C
SLIDE 3	GRIDS II	SLIDE 4	
SLIDE 1	GRIDS I	SLIDE 2	

Purpose:

To determine the particle size distribution of contaminants deposited on like surfaces exposed at different angles of orientation during the contamination process.

Procedure:

Eighteen glass microscope slides 2-1/2 by 1-1/2 cm (with electron microscope grids affixed as shown above) mounted on wooden forms at various angular orientations, were exposed in sliding trays at each station. After recovery, the contaminant was fixed in place by spraying with plastic.

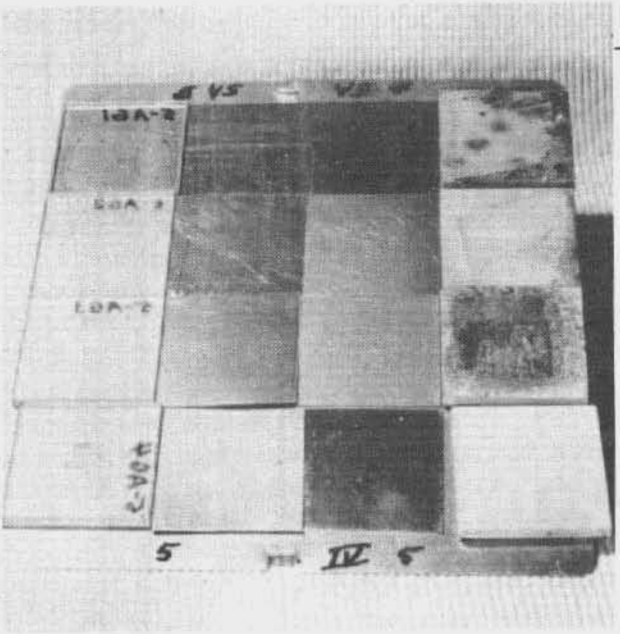
Data Taken:

Activity counts, electron micrographs, photomicrographs, and particle size measurements.

Results and Discussion:

See Sec. 8.4.2.

Fig. 8.5 Influence of Angular Orientation of Surface on Particle Size Distribution



Purpose:

To determine the influence of surface roughness and hardness on the contamination-decontamination behavior of materials.

Procedure:

Ten samples of glass, ten of tile, and eight of aluminum, each 2-1/2 in. sq, were exposed in sliding tray containers at each station. The glass and tile sets each exhibited six grades of surface roughness. Four samples in each aluminum set were coated with polyisobutylene, and four with polyvinylacetate, each coating yielding four grades of hardness. Samples were treated by wet decontamination techniques.

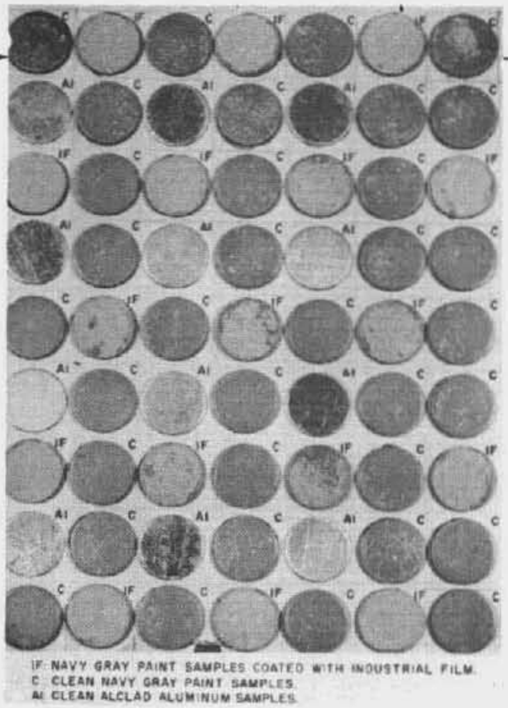
Data Taken:

Surface roughness and hardness measurements, and activity counts before and after decontamination.

Results and Discussion:

See Sec. 8.4.3.

Fig. 8.6 Influence of Surface Roughness and Hardness on Contamination-decontamination of Materials



Purpose:

To compare the contamination-decontamination behavior of deliberately soiled and scrupulously clean surfaces.

Procedure:

Sixty brass disks 1 in. in diameter and 1/8 in. thick, painted Navy gray, were attached to aluminum sheets and exposed in sliding trays at each station. Twenty disks in each set were deliberately soiled with an artificially created industrial film. Wet decontamination techniques were used.

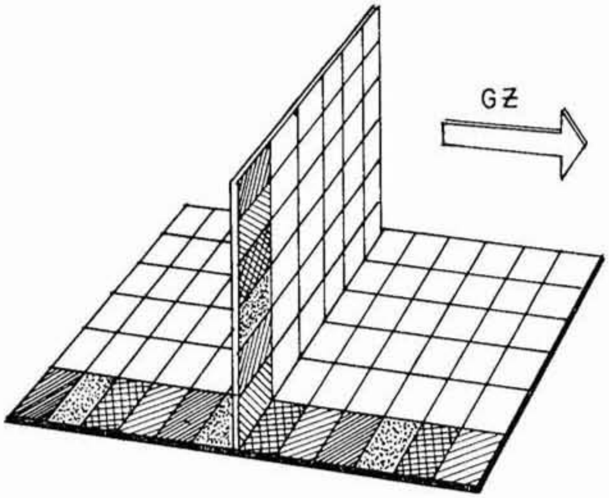
Data Taken:

Activity counts and autoradiographs before and after decontamination.

Results and Discussion:

See Sec. 8.4.4.

Fig. 8.7 Contamination-decontamination Behavior of Clean and Deliberately Soiled Surfaces



Purpose:

To investigate the contamination-decontamination behavior of field-contaminated materials in order to improve techniques for evaluating the radiological characteristics of materials.

Procedure:

One and one-quarter inch square samples of Navy gray paint on anodized aluminum, bare anodized aluminum, chromium-nickel steel, and window glass were mounted on plywood panels for exposure. Panels were placed vertically and horizontally, facing toward and away from ground zero. Both wet and dry decontamination techniques were used.

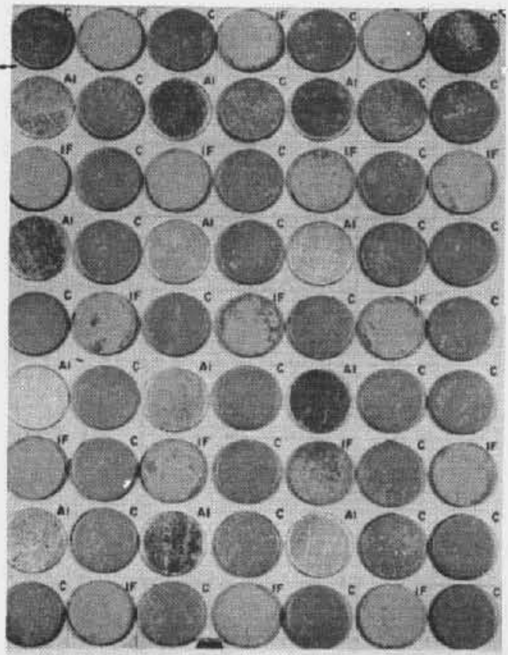
Data Taken:

Activity count and autoradiograph of each sample before and after decontamination.

Results and Discussion:

See Sec. 8.4.5.

Fig. 8.8 Contamination-decontamination Behavior of Selected Materials



IF: NAVY GRAY PAINT SAMPLES COATED WITH INDUSTRIAL FILM.
C: CLEAN NAVY GRAY PAINT SAMPLES.
Al: CLEAN ALCLAD ALUMINUM SAMPLES.

Purpose:

To investigate the efficiency of selected decontaminating agents on solid particulate contamination from an atomic bomb detonation.

Procedure:

Sixty aluminum disks 1 in. in diameter and 1/8 in. thick were attached to aluminum sheets and exposed in sliding trays at each station. Twenty disks in each set were Alclad aluminum, and forty were painted with Navy gray. Selected wet decontaminating agents were tested on these disks.

Data Taken:

Activity counts and autoradiographs before and after decontamination.

Results and Discussion:

See Sec. 8.4.6.

Fig. 8.9 Investigation of Selected Decontaminating Agents

TABLE 8.1

Contamination on Top Horizontal Surfaces vs Contamination on Inclined Surfaces Shielded from Vertical Fall-out

Top Horizontal Contamination / Non-horizontal Contamination(a)	Per Cent of Comparisons Equal to or Greater Than Noted Ratio(b)
40:1	3
30:1	16
20:1	26
10:1	29
5:1	37
1:1	68

(a) Contamination on 30°, 45°, 60°, 75°, and 90° surfaces.

(b) Thirty-eight comparisons were made.

TABLE 8.2

Contamination on Base Horizontal Surfaces vs Contamination on Inclined Surfaces Exposed to Vertical Fall-out

Base Horizontal Contamination / Non-horizontal Contamination(a)	Per Cent of Comparisons Equal to or Greater Than Noted Ratio(b)
30:1	0
20:1	3
10:1	5
5:1	16
1:1	53

(a) Contamination on 90°, 120°, 135°, and 150° surfaces.

(b) Sixty-two comparisons were made.

The values listed in Tables 8.1 and 8.2 indicate that the horizontal surface becomes contaminated to a greater extent than does the non-horizontal surface. It is seen that in a number of cases the contamination difference is quite significant. In a few instances the contamination ratio is large, on the order of 30 and 40 to 1. Only three occurrences were found where the horizontal to non-horizontal contamination ratio approached 100 to 1.

In the main, large horizontal to non-horizontal contamination ratios occurred with forms which had been exposed at highly contaminated stations. Samples at these stations were covered with a rather thick, discontinuous coating of contaminated matter. The majority of the large ratios observed was due simply to formation of successive layers of this active matter on the horizontal surface.

Another reason for the large contamination ratios was the existence of isolated particulates which were much more radioactive than the bulk of the contaminated particles. At times, the activity on a surface was concentrated in a relatively small number of these extremely active particulates. As a nonuniform activity distribution was found on the surfaces, the very "hot" particles created a few situations of large horizontal to non-horizontal contamination differences.

It is assumed that the procedures used to recover and return samples caused a redistribution on the forms of the thick activity deposits. If better sample recovery (and transport) techniques had been available, it is probable that a greater incidence of large horizontal to non-horizontal contamination ratios would have been observed.

This investigation found no significant difference between contamination on surfaces facing the point of detonation, and surfaces facing away from the point of detonation. Similar results were obtained in the investigations reported in 8.4.2 and 8.4.5.

8.4.2 Influence of the Angular Orientation of Surfaces on the Particle Size Distribution of Contaminant Deposited

Before particle size measurements were made, the activity level of the contaminants found on each slide were determined as recorded in Table 8.3.

An examination of Table 8.3 shows that the results obtained with Surface Shot materials are very random. This is doubtlessly due to damage caused by the indirect exposure of the samples to the combined windstorm and rainstorm.

Although the values obtained with Surface Shot slides vary, they tend to follow the same pattern found for the Underground Shot. The data of both shots show that the vertical orientation collected less activity. There was very little difference in the activity found on the inclined and on the horizontal orientations. This result is somewhat surprising, since it seems logical to suppose that some gradation in activity should occur as the orientation of a surface is gradually changed from horizontal to vertical. Indeed, other investigators have noted a few activity ratios as high as 20 to 1 for some horizontal to inclined surface orientations (cf. Sec. 8.4.1). It appears that further investigation in the laboratory is necessary before it can be decided how radioactivity deposition varies in the case of horizontal and inclined surfaces.

TABLE 8.3

Activity Ratios on Microscope Slides Exposed at Different Orientations

Detonation	Station	Ratio of Activities			
		Front Vertical / Front Horizontal	Front 45° Angle / Front Horizontal	Rear 45° Angle / Rear Horizontal	Rear Vertical / Rear Horizontal
Surface	1	0.32	10.7	0.40	0.12
	3	0.94	1.88	29.0	0.58
	5	0.25	16.8	0.99	0.15
Underground	9	0.33	1.7	0.99	0.22
	10	0.23	1.5	2.0	0.11
	13	0.20	0.84	0.87	0.18
	14	--	--	0.78	0.20

Results obtained by measurement of particle size are reported in 1. and 2. below:

1. <u>Optical Microscope</u>.

Since the Surface Shot samples were exposed to adverse weather conditions, it was felt that the results would probably be inconclusive. Therefore, it was decided that only the Underground Shot samples should be measured and reported. The particle sizes measured with an optical microscope are reported as mean diameters in Table 8.4. Their composite average is also given. The latter value is the average of all the values at a particular orientation for all stations examined. All future remarks regarding the data will refer to these values.

Because of the limit of the resolving power of the emulsion used in autoradiographing the slides, it was impossible to measure accurately particle sizes below two microns with the optical microscope; hence, all particles below this size were reported as having one value, that of the average particle size obtained with the electron microscope.

TABLE 8.4

Particle Size as a Function of Orientation for Underground Shot Particulates

Station	Slide Orientation	Total Number of Particles, N	Mean Diameter[(a)], $\bar{d}_s$ (microns)	Composite Average[(b)], $\bar{d}$ (microns)
9	Horizontal (180°)	86	7.8	
10	Horizontal (Slide 1)	329	12.1	
	Horizontal (Slide 2)	214	8.5	
	Horizontal (Slide 3)	372	12.1	
13	Horizontal (Slide 1)	138	9.9	
	Horizontal (Slide 2)	681	9.2	
14	Horizontal (Slide 1)	190	9.2	
	Horizontal (Slide 2)	115	8.5	
				10.5
9	Vertical (90°)			
9	Vertical (Slide 1)	275	11.4	
	Vertical (Slide 2)	155	9.9	
	Vertical (Slide 3)	259	12.1	
	Vertical (Slide 4)	91	8.5	
10	Vertical (Slide 1)	63	8.9	
	Vertical (Slide 2)	73	6.4	
	Vertical (Slide 3)	327	10.7	
	Vertical (Slide 4)	154	11.4	
13	Vertical (Slide 1)	375	12.8	
	Vertical (Slide 2)	315	9.9	
	Vertical (Slide 3)	319	9.2	
	Vertical (Slide 4)	323	7.8	
14	Vertical	22	4.3	
				10.3
9	Inclined (45°)	289	14.2	
10	Inclined	208	11.4	
13	Inclined (Slide 1)	973	14.2	
	Inclined (Slide 2)	592	12.8	
14	Inclined	52	5.0	
				13.3

(a) $\bar{d}_s = \sum \frac{n_i d_i}{N_s}$, where n_i = number of particles in ith interval.
d_i = particle size at ith interval.
$N_s = \sum n_i$ for one station.

(b) Composite Average $\bar{d} = \sum \frac{N_s \bar{d}_s}{N_T}$, where N_T = number of particles for one orientation at all stations.

The results show no great difference in particle size between the three orientations. Although the angular value is larger than the horizontal value, the difference is believed not to be significant in respect to material contaminability. Indeed, the radioactivity ratio of inclined to horizontal surfaces in Table 8.3 shows that the inclined surface is contaminated only slightly more than the horizontal one.

2. Electron Microscope.

The comparison of the results of particle size measurements with the electron microscope grids exposed at Surface and Underground Shots with those obtained from optical microscope measurements indicates that again all three surface orientations held particles which did not differ in size by any gross amount. Table 8.5 compares the particle diameters found, with both the optical and electron microscope, at different orientations; the values again show that the vertical surface contains the smallest particle. Although some difference in the inclined to horizontal ratios exist, all of the values are close to unity.

TABLE 8.5

Ratios of Composite Average Diameters of Particulates

Detonation	Method of Measurement	Composite Average Diameters[a]	
		Vertical Orientation / Horizontal Orientation	Inclined Orientation / Horizontal Orientation
Surface	Electron Microscope	0.66	0.73
Underground	Electron Microscope	0.70	1.00
Underground	Optical Microscope	0.98	1.26

(a) See Table 8.4.

A plot of particle number, n, versus particle diameter, d, is shown in Fig. 8.10 and includes data from both optical and electron microscope measurements for all orientations. However, since the points from both types of measurement lie very close to one another, only a single line has been drawn. The number of particles represented in the electron microscope measurements have been normalized on this curve so that a smooth extrapolation between the two curves is possible. The combined curve gives a hyperbolic distribution with linear coordinates. The plot of particle diameter, d, versus cumulative frequency has been constructed from the data obtained with Underground Shot slides (Fig. 8.11). It is reported to show that despite differences in slope the curves obtained at all orientations have similar trends.

An examination of the results obtained leads to the conclusion that, under the conditions of the Operation JANGLE experiment, the particle size of deposited contaminant did not vary a great deal with surface orientation. It should be pointed out, however, that the particle size measured in this experiment does not represent the true fall-out from the burst. To have done this, it would have been necessary to have had available a better procedure for the recovery and return of the samples to the laboratory. Due to the rough treatment received by the samples before measurement, it must be concluded that the results derive from a particle size which adhered to the surface after being subjected to such mild decontamination as would be achieved by jolting and jarring. This does not invalidate the importance of the results, for it is reasonable to assume that the particles which adhere to a surface represent a contamination hazard which must be evaluated. Therefore, a knowledge of the particle size measured in the present study is of extreme importance in decontamination phenomenology.

Differences were observed between the radioactivity ratios and the particle size ratios for the vertical to horizontal surface orientation. Although the presence of a larger particle size on the horizontal surface could lead to identical results, it is believed that these differences can be reconciled by considering that more particles of comparative size are retained by the horizontal surface than by the vertical surface.

8.4.3 Influence of Surface Roughness and Surface Hardness on the Contamination and Decontamination of Materials

Samples were subjected to some wind and rain after the Surface detonation. These weather conditions undoubtedly influenced the nature of the contaminant on the specimens. For this reason, it is felt that results obtained with materials contaminated by the Surface Shot are not as reliable as results obtained with Underground Shot materials.

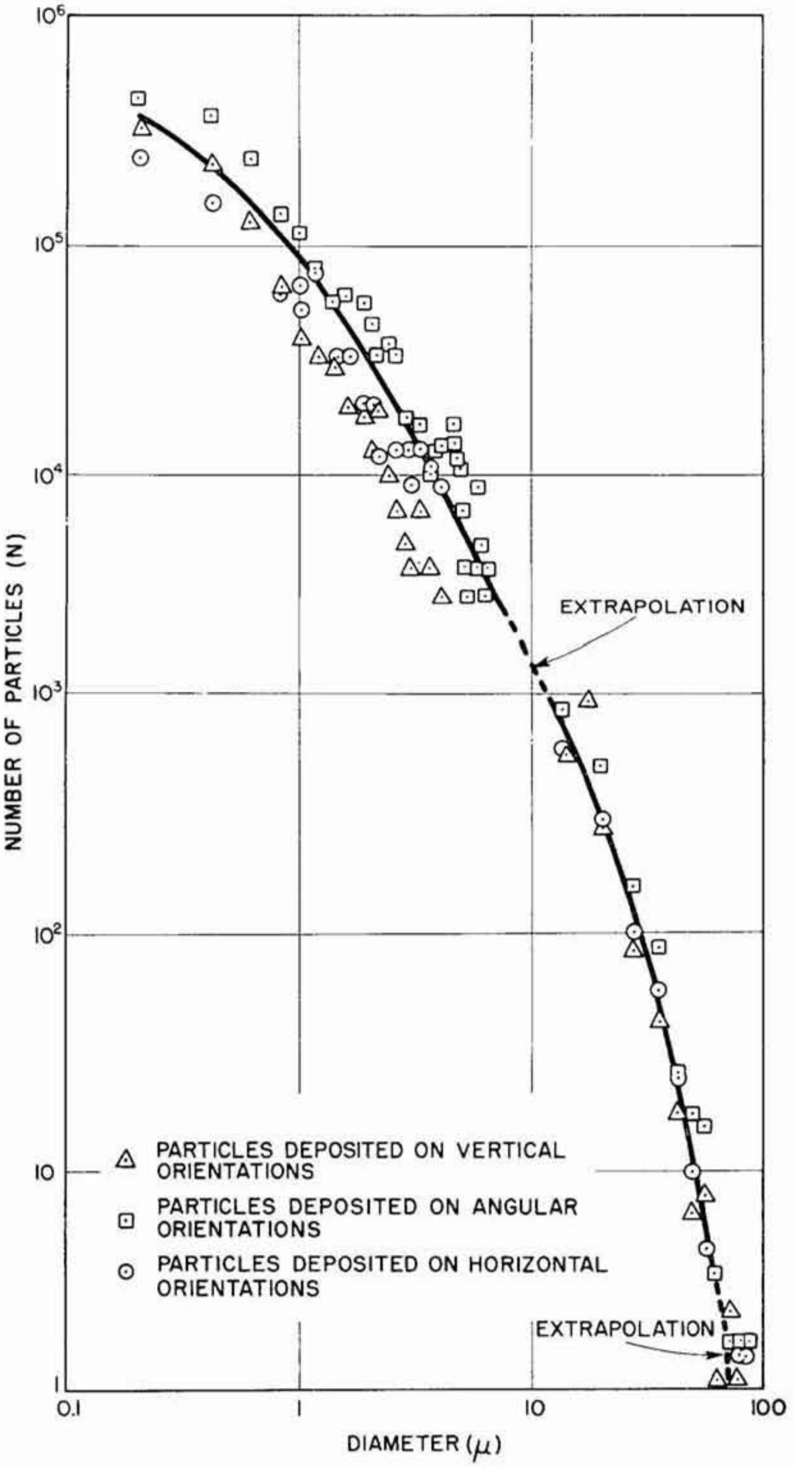


Fig. 8.10 Particle Number vs Particle Diameter

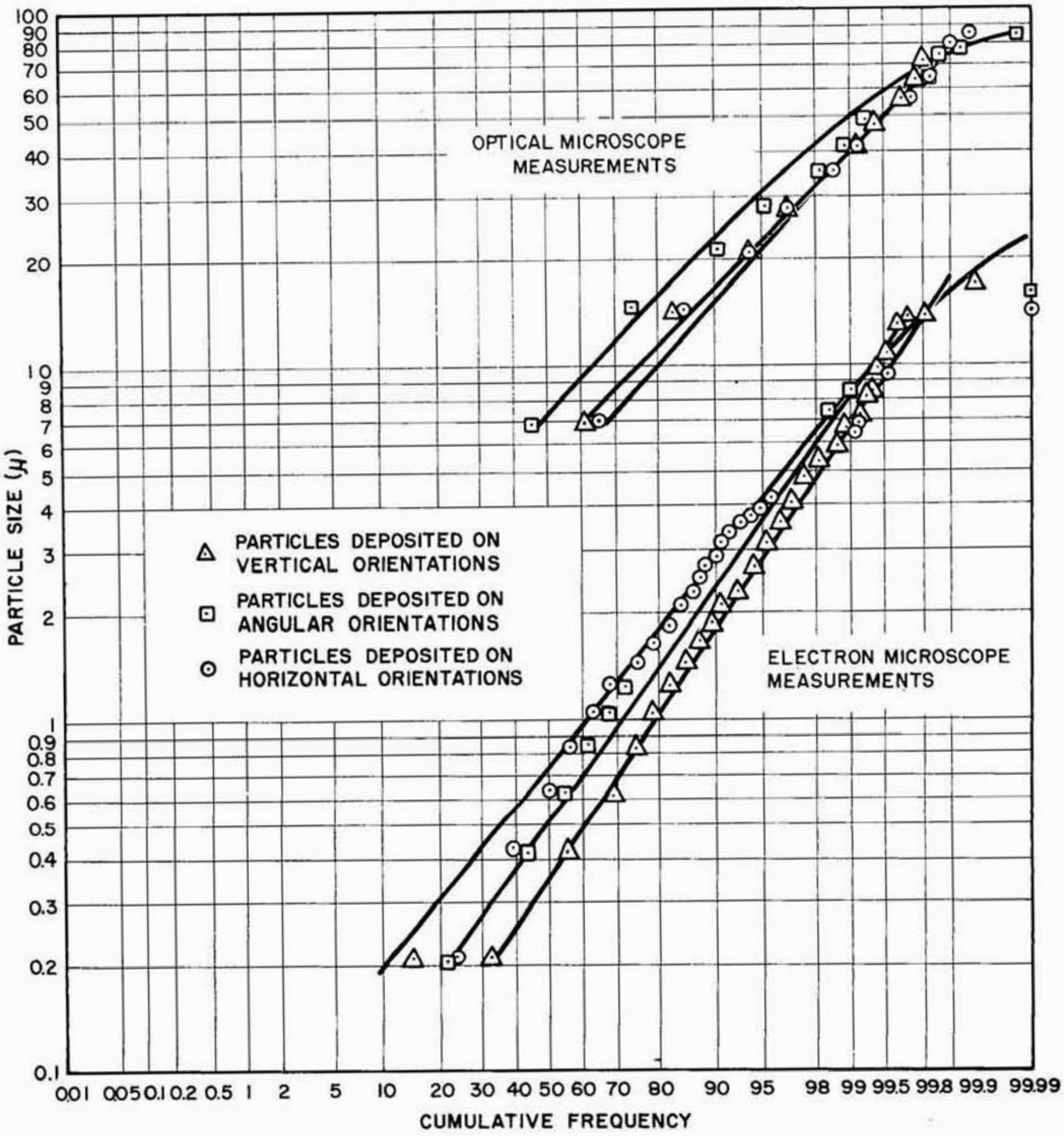


Fig. 8.11 Particle Diameter vs Cumulative Frequency

[redacted]

8.4.3.1 Roughness Studies

Analysis of the data secured with glass and tile specimens showed that the contamination-decontamination behavior of the tile was quite erratic.

The irregular action of the tile was probably due to the porosity of this material. Examination of the tile surfaces revealed interstices whose size was as large as 20 microns. The investigations of Sec. 8.4.2 found a large percentage of the deposited activity to be particulates having a size in the order of 1-2 microns. It is quite conceivable that these small particles actually became lodged in the porous structure of the tile, and that subsurface rather than surface contamination occurred. Some evidence for assuming subsurface contamination appears in comparison of results obtained with tile exposed at the Surface Shot, with results obtained with tile exposed at the Underground Shot. Rain after the Surface Shot may very likely have transported particles below the tile surface; therefore, it was expected that the Surface Shot results would be even more erratic than Underground Shot results. This was actually found to be the case.

The discussion below is concerned with the measurements carried out with the glass specimens exposed at both detonations. The amounts of contamination found on the surfaces are reported graphically. Figs. 8.12 and 8.13 show the results obtained with two groups of samples contaminated by the Underground Shot; Fig. 8.14 reports the results of measurements of samples contaminated by the Surface Shot. Each value in Fig. 8.12 and Fig. 8.14 is the mean value obtained with three samples, and in Fig. 8.13 each value is the mean of five samples.

The graphs do not permit definite conclusions regarding the manner in which roughness influenced the contaminability of materials exposed to radioactive fall-out. The least reliable curve (Fig. 8.14) indicates a decreasing contaminability with increasing roughness. The Underground Shot curves show in one case essentially no effect of roughness, and, in the other case, an increasing contaminability with increasing roughness.

It appears from Fig. 8.15 that the percentage decontamination achieved was a function of surface roughness. Derivation of the graphs was based on an assumption of a constant level of initial contaminant in each tray. The curves indicate that, in general, an increased roughness of surface led to a decreased percentage decontaminability. This apparently is the case for specimens exposed at both the Surface and Underground Shots.

In the decontamination graphs for the Underground Shot samples included in Figs. 8.12 and 8.13, the curves show, in the

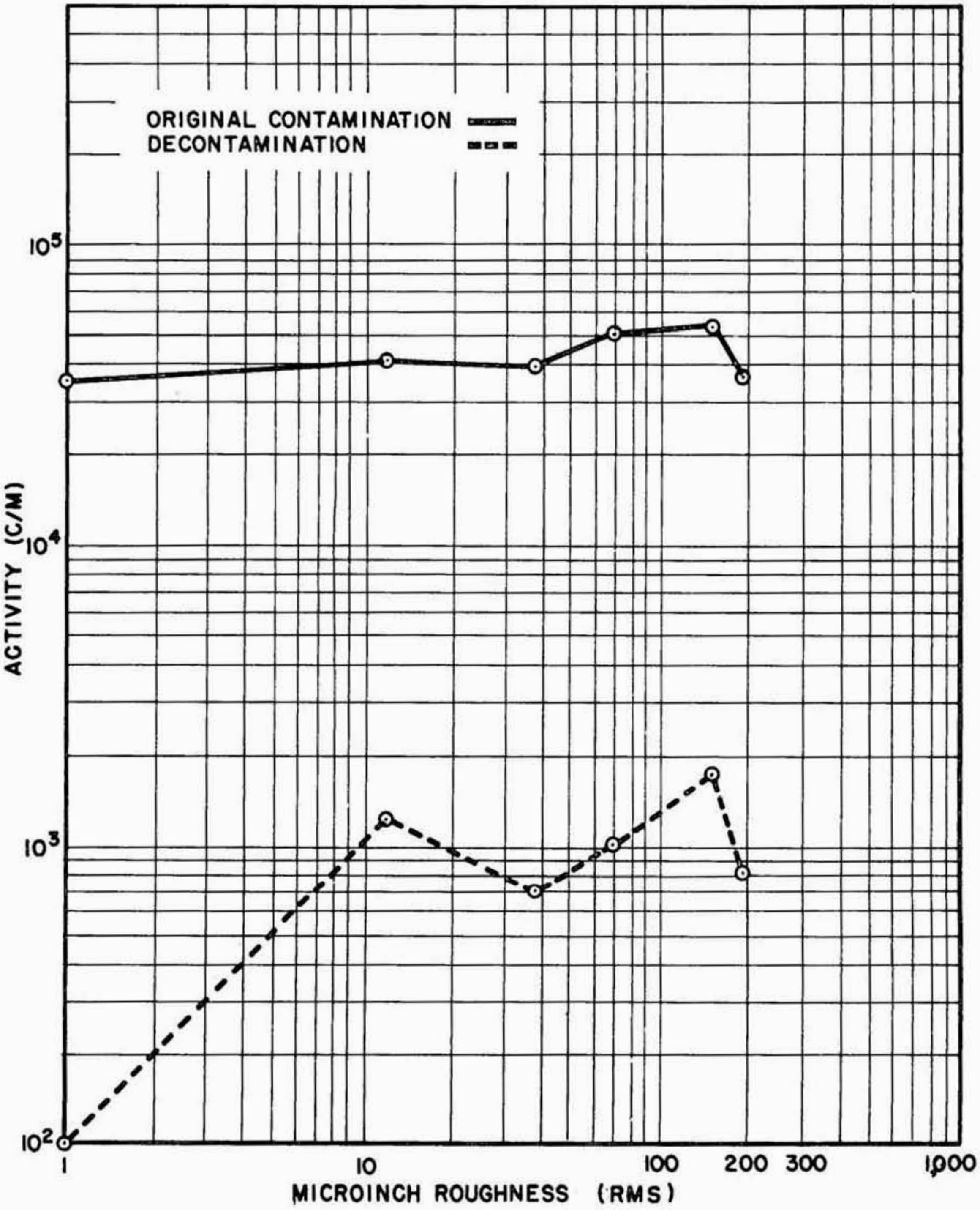


Fig. 8.12 Contamination-decontamination Behavior of Glass Specimens Exposed in Containers 9B and 14B at Underground Shot and Decontaminated by Sponging

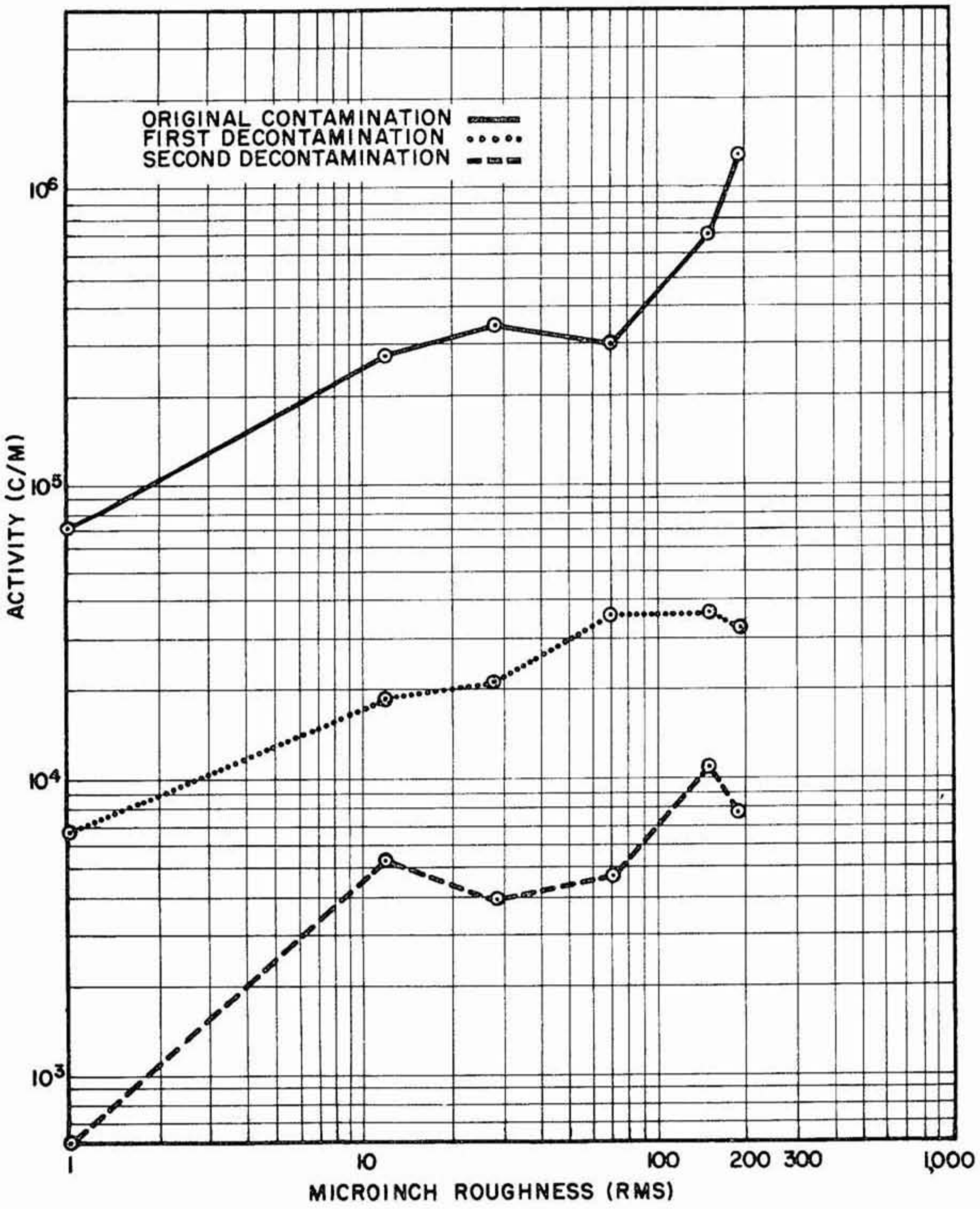


Fig. 8.13 Contamination-decontamination Behavior of Glass Specimens Exposed in Containers 9A, 10A, 13B at Underground Shot and Decontaminated by Washing and Sponging

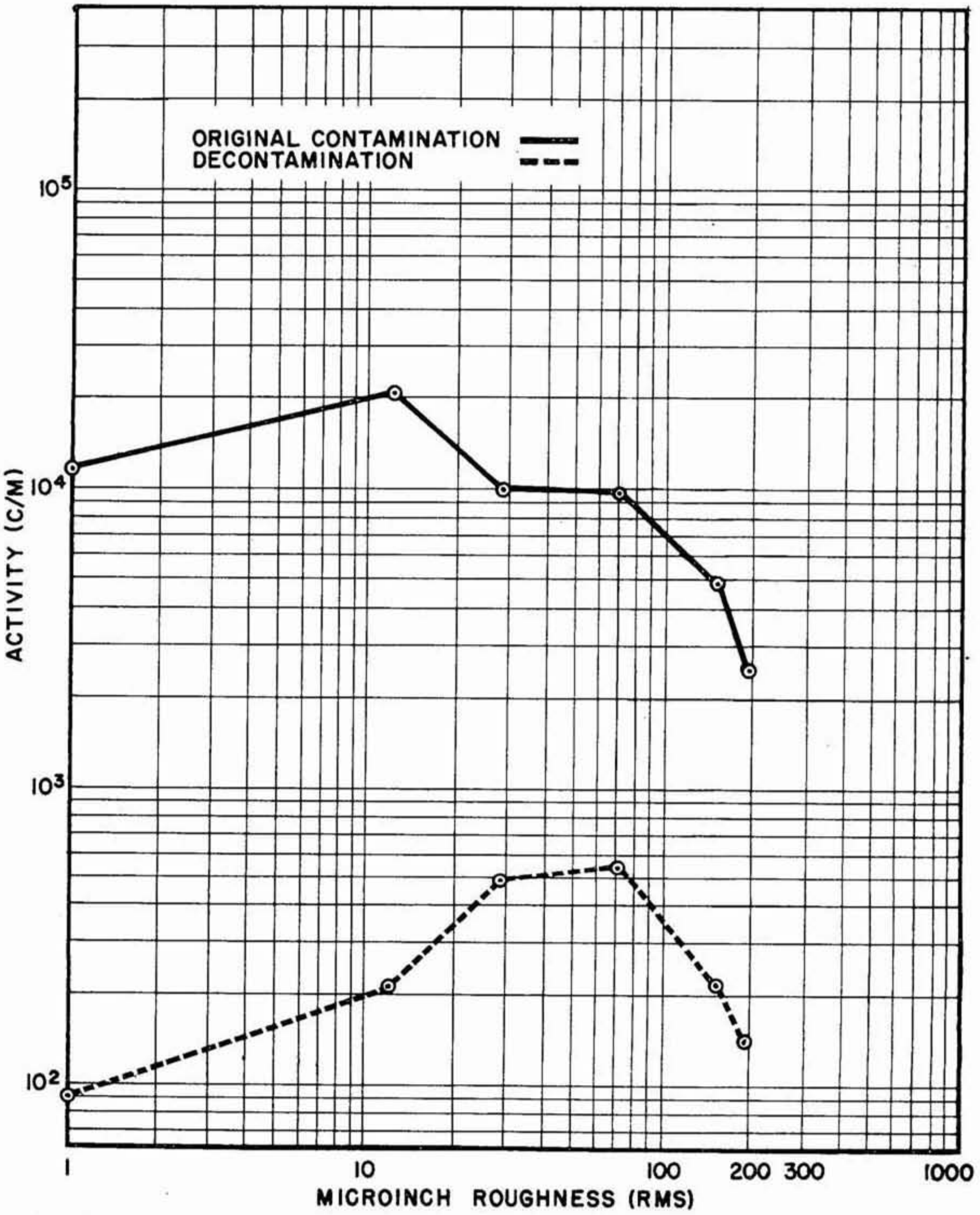


Fig. 8.14 Contamination-decontamination Behavior of Glass Specimens Exposed at Surface Shot and Decontaminated by Sponging

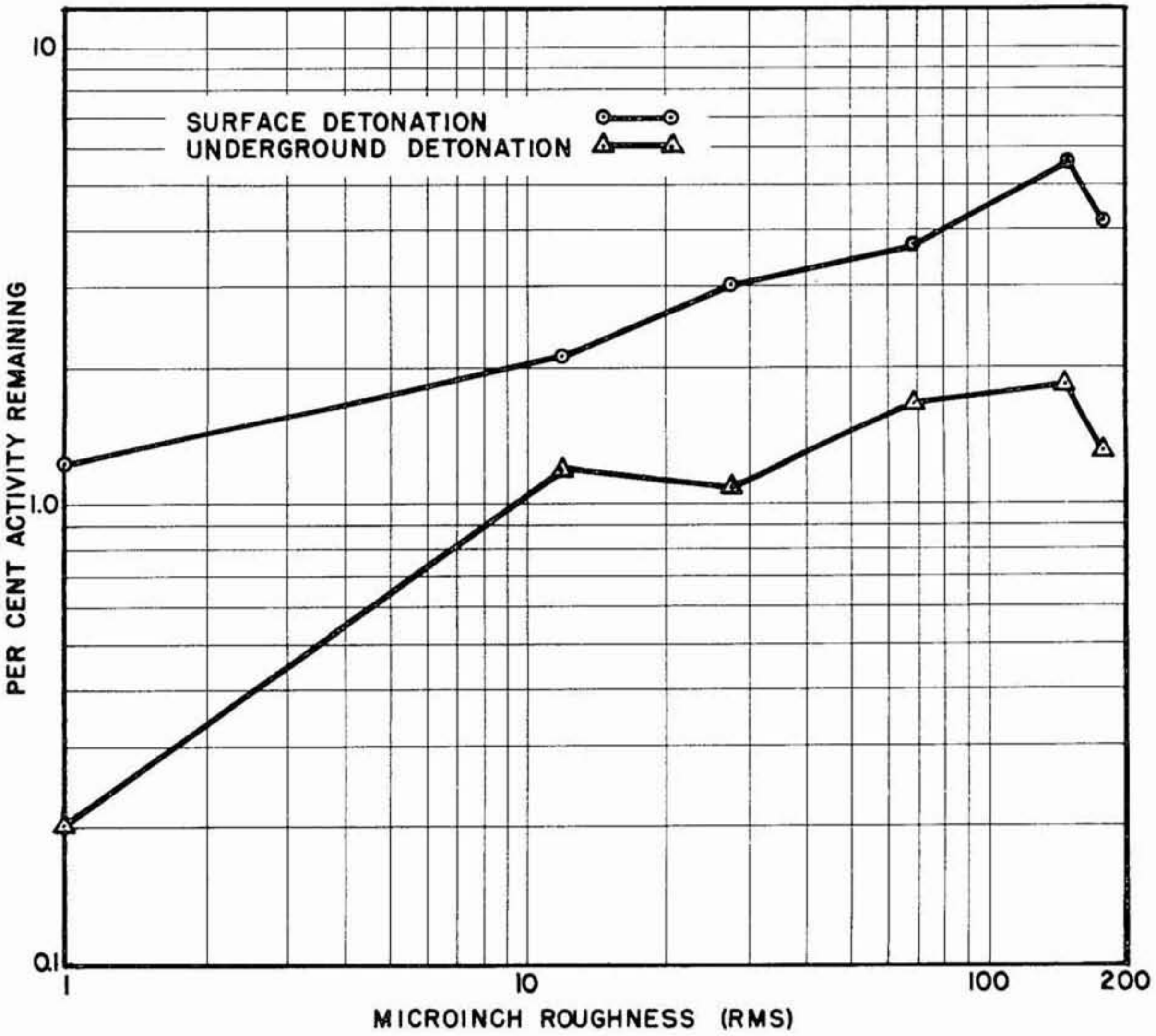


Fig. 8.15 Per Cent Decontamination Achieved with Glass Specimens

over-all sense, that the quantity of activity which remained after decontamination increased with increased surface roughness. Note that this appears to be true for both sponge and water decontamination. The decontamination curve for Surface Shot materials (Fig. 8.14) only partially substantiates the evidence obtained from the materials exposed at the Underground Shot. With Surface Shot samples, a decreased contaminant retention appeared with roughnesses greater than approximately 100 microinches. However, it is quite probable that with Surface Shot samples the decreased contaminant retention was a function of the decreased contamination found on roughnesses greater than 100 microinches.

Although, at any given roughness, the percentage activity remaining on Surface Shot samples exceeds that on Underground Shot samples, the initial contamination found on Underground Shot samples was much greater than that found on Surface Shot samples. As a consequence, after sponge decontamination, a greater quantity of contaminant remained at comparable surface roughnesses, on materials exposed at the Underground detonation.

8.4.3.2 Hardness Studies

Results obtained with the hardness specimens are shown in Tables 8.6 and 8.7. In the case of isobutylene specimens contaminated at the Surface Shot, the amounts of contaminant detected on the softer surfaces (I and II) far exceeded that detected on the harder surfaces (III and IV). Isobutylene surfaces exposed at the Underground detonation behaved in a like manner, but to a lesser extent. Thus, on the basis of the isobutylene data, it is possible to tentatively postulate (subject to the sample recovery and transport procedures employed) that, under Operation JANGLE contaminating conditions, soft surfaces contaminate to a greater extent than do hard surfaces.

TABLE 8.6

Influence of Surface Hardness on Contamination-decontamination Behavior of Materials Exposed at the Surface Shot

Material	Hardness Values[(a)]		Average Initial Contamination ($c/m \times 10^{-3}$)	Average Sponge Decontamination	
	Sward No. (Mode)	Tukon No.[(b)]		Contamination Remaining ($c/m \times 10^{-3}$)	Contamination Remaining (per cent)
Isobutylene I	8	67	430	4.22	2.98
Isobutylene II	10	79	432	6.24	1.4
Isobutylene III	22	92	44.6	2.16	4.9
Isobutylene IV	26	87	42.1	1.82	4.3

TABLE 8.6 (Continued)

Influence of Surface Hardness on Contamination-decontamination Behavior of Materials Exposed at the Surface Shot

Material	Hardness Values[a]		Average Initial Contamination (c/m × 10^{-3})	Average Sponge Decontamination	
	Sward No. (Mode)	Tukon No.[b]		Contamination Remaining (c/m × 10^{-3})	Contamination Remaining (per cent)
Polyacetate I	26	4.3	226	0.564	0.25
Polyacetate II	18	2.4	130	0.605	0.47
Polyacetate III	24	7.1	115	0.200	0.17
Polyacetate IV	33	8.3	38.8	0.303	0.78

[a] The greater the Sward No. (or Tukon No.) the greater the hardness.

[b] Each value is the mean of fifteen determinations with 10, 25, and 50 gram loads.

TABLE 8.7

Influence of Surface Hardness on the Contamination-decontamination Behavior of Materials Exposed at the Underground Shot

Material	Hardness Values[a]		Average Initial Contamination (c/m× 10^{-3})	Average Sponge Decontamination (c/m × 10^{-3})	Average Water Wash Plus Sponge Decontamination		
	Sward No. (Mode)	Tukon No.[b]			Contamination after Water Wash (c/m × 10^{-3})	Contamination after Sponging (c/m × 10^{-3})	Contamination Remaining Based on Initial Contamination (per cent)
Isobutylene I	8	67	1,740	1.45	1,050	73.6	4.2
Isobutylene II	10	79	1,100	0.58	744	59.6	5.4
Isobutylene III	22	92	692	0.38	514	27.0	3.9
Isobutylene IV	26	87	1,090	0.39	667	23.0	2.1
Polyacetate I	26	4.3	306		70.0	25.0	8.2
Polyacetate II	18	2.4	474		54.0	22.2	4.7
Polyacetate III	24	7.1	259		56.0	16.8	6.5
Polyacetate IV	33	8.3	301		63.0	31.2	10

[a] The greater the Sward No. (or Tukon No.) the greater the hardness.

[b] Each value is the mean of fifteen determinations with 10, 25, and 50 gram loads.

Sward and Tukon tests adequately classified the relative hardness of only two members of the polyacetate series. It was determined that polyacetate II was softer than polyacetate IV. The contamination data secured with these two polyacetate surfaces support the supposition of the paragraph above. With samples exposed at both Surface and Underground detonations, it was found that polyacetate II was contaminated to a greater extent than polyacetate IV.

Soft and hard surface contamination differences ranged by a factor of from 1-1/2 to 10. Note that the large differences were obtained with Surface Shot materials. These large differences probably were partially due to the wind and rain following Surface Shot.

Hard isobutylene surfaces decontaminated to a lower level than did soft isobutylene surfaces; residual contamination on soft surfaces was approximately two to three times that on hard surfaces.

Decontamination results obtained with polyacetate II and IV samples are contradictory. With Surface Shot materials, twice the amount of activity remained on polyacetate II after decontamination as remained on polyacetate IV. After decontamination of Underground Shot specimens, it was found that more activity remained on polyacetate IV than on polyacetate II.

8.4.4 Contamination-decontamination Characteristics of Clean and Laboratory Soiled Surfaces

Samples coated with industrial film retained contamination to a greater extent than did clean samples. This difference is shown in Fig. 8.16, a photograph and autoradiograph of a contaminated sample panel. The light colored specks and areas on the samples in the photograph are deposits of contaminant as indicated by comparison of photograph and autoradiograph. In this comparison, the light specks and areas on a sample match closely the dark specks and areas on the autoradiograph made by the sample.

The counting data in Tables 8.8 and 8.9 were derived with materials exposed at two stations. These data illustrate the difference in retention of contamination by clean and industrial-filmed paint samples. The ratios of the initial activities of industrial-filmed samples to the initial activities of clean samples, computed from the data of Tables 8.8 and 8.9 are 7.5 and 2.0, respectively.

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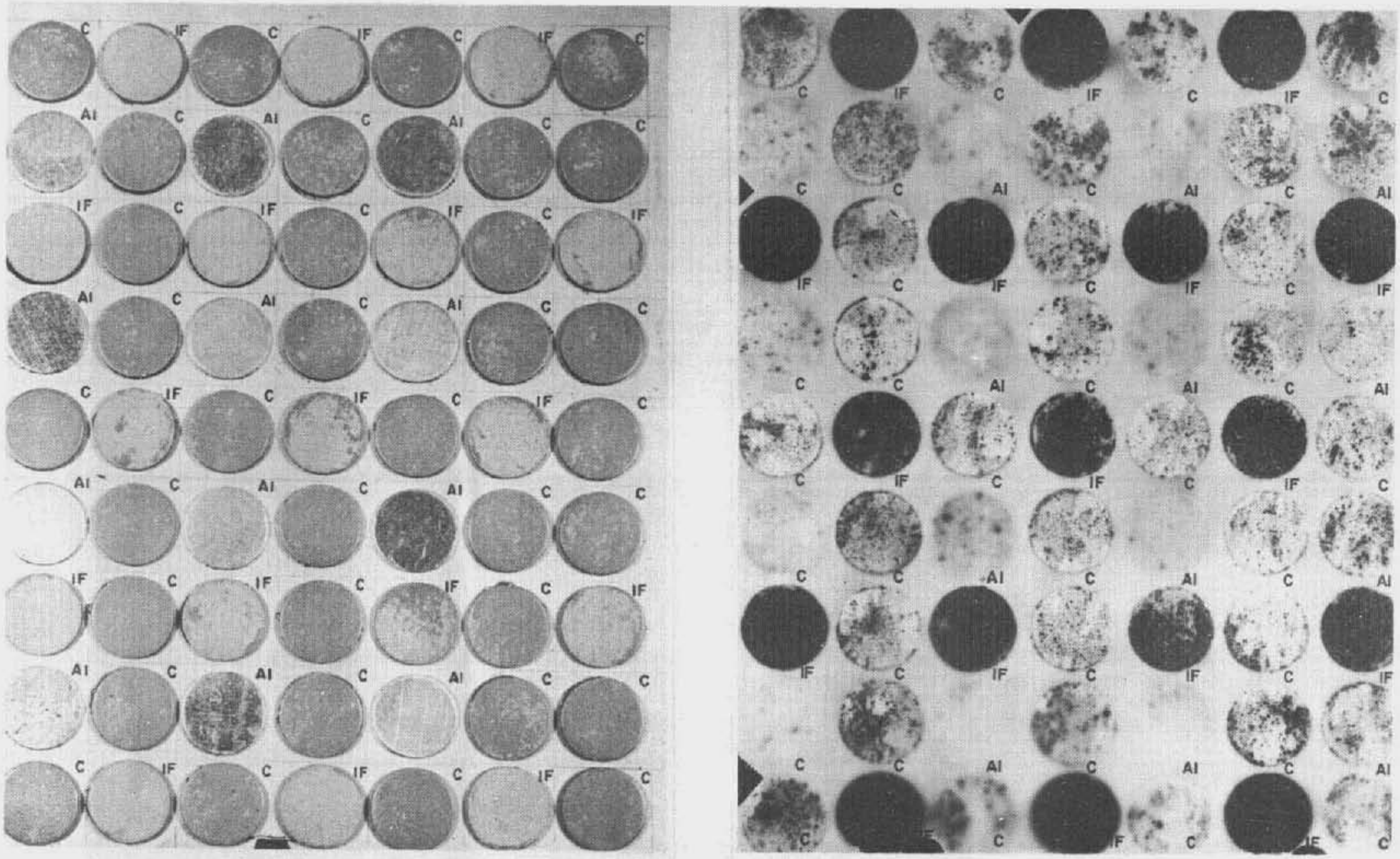
Security Information



IF: NAVY GRAY PAINT SAMPLES COATED WITH INDUSTRIAL FILM
C: CLEAN NAVY GRAY PAINT SAMPLES
Al: CLEAN ALCLAD ALUMINUM SAMPLES. (NOT IN FOCUS AS THEY
WERE THINNER THAN THE PAINT SAMPLES.)

Fig. 8.16 Photograph and Autoradiograph of Sample Panel

[redacted]

Security Information

TABLE 8.8

Decontamination of Clean and Soiled Navy Gray Paint Samples Exposed (Station 13)

Decontaminating Agent	Type of Samples[a]	Average Initial Activity ($c/m \times 10^{-3}$)[b]	Activity after Decontamination ($c/m \times 10^{-3}$)		
			For 1 min	For 6 min	For 20 min
Na_4(EDTA)[c]	Clean	52.0	1.08	0.73	0.37
Na_4(EDTA)	Clean	37.8	1.16	0.98	0.53
		Av 44.9	1.12	0.86	0.45
Na_4(EDTA)	Soiled	305	1.48	0.87	0.78
Na_4(EDTA)	Soiled	338	0.79	0.55	0.49
		Av 332	1.14	0.71	0.64
Water	Clean	57.7	3.12	2.60	2.13
Water	Clean	40.6	5.26	5.03	4.68
		Av 49.2	4.19	3.82	3.41
Water	Soiled	309	9.23	7.35	6.04
Water	Soiled	346	14.3	12.6	10.8
		Av 328	11.8	9.98	8.42
Tide	Clean	54.4	0.66	0.37	0.31
Tide	Clean	39.5	1.13	1.02	0.88
		Av 47.0	0.90	0.70	0.60
Tide	Soiled	310	1.09	0.70	0.53
Tide	Soiled	403	1.00	0.52	0.38
		Av 357	1.05	0.61	0.46
$Na_5P_3O_{10}$[d]	Clean	56.1	1.11	0.81	0.71
$Na_5P_3O_{10}$	Clean	39.0	1.28	1.17	1.07
		Av 47.6	1.20	0.99	0.89
$Na_5P_3O_{10}$	Soiled	307	2.17	1.04	0.69
$Na_5P_3O_{10}$	Soiled	467	0.79	0.59	0.51
		Av 387	1.48	0.82	0.60
Duponol C	Clean	49.7	1.19	0.92	0.68
Duponol C	Clean	38.2	1.58	1.40	1.26
		Av 44.0	1.39	1.16	0.97
Duponol C	Soiled	328	2.29	1.52	1.02
Duponol C	Soiled	342	2.68	1.59	1.09
		Av 335	2.49	1.56	1.06

(a) Two samples were used in each experiment.

(b) All activities were corrected to 11 Dec 1951.

(c) Na_4(EDTA) indicates tetrasodium ethylenediaminetetraacetate.

(d) $Na_5P_3O_{10}$ designates sodium tripolyphosphate.

TABLE 8.9

Decontamination of Clean and Soiled Navy Gray Paint Samples
(Station 10)

Decontaminating Agent	Type of Samples(a)	Average Initial Activity (c/m × 10^{-3})(b)	Activity after Decontamination (c/m × 10^{-3})		
			For 1 min	For 6 min	For 20 min
Na_4(EDTA)(c)	Clean	208	2.36	1.85	1.29
Na_4(EDTA)	Soiled	323	0.69	0.52	0.46
Water	Clean	130	7.85	6.53	6.16
Water	Soiled	318	27.4	15.8	14.6
Tide	Clean	155	1.65	0.81	0.78
Tide	Soiled	331	0.66	0.43	0.34
$Na_5P_3O_{10}$(d)	Clean	170	2.12	1.71	1.67
$Na_5P_3O_{10}$	Soiled	318	0.60	0.46	0.40
Duponol C	Clean	217	3.78	3.02	2.82
Duponol C	Soiled	349	4.04	2.72	2.08

(a) Two samples were used in each experiment.

(b) All activities were corrected to 11 Dec 1951.

(c) Na_4(EDTA) indicates tetrasodium ethylenediaminetetraacetate.

(d) $Na_5P_3O_{10}$ designates sodium tripolyphosphate.

Data for comparison of the decontamination characteristics of clean and industrial-filmed samples exposed at Stations 13 and 10, are provided in these tables. The values listed permit the following interpretations:

1. Decontamination was rapid for both clean and industrial-filmed samples; most radioactivity was removed by the 1-min treatment as shown in Fig. 8.17.

2. After decontamination by water washing, industrial-filmed samples were more radioactive than clean samples.

3. The use of chemical additives was advantageous in the decontamination test employed. The increased decontamination attained with chemical additives in <u>distilled water</u> with clean and soiled Navy gray paint is shown numerically in Table 8.10 by the ratios comparing the 1-min decontamination by water to the 1-min decontamination by additive.

4. Concerning clean and industrial-filmed samples that had been decontaminated with the same additive, the industrial-filmed samples (in spite of their greater initial activity) were less radioactive than or approximately as radioactive as the clean samples.

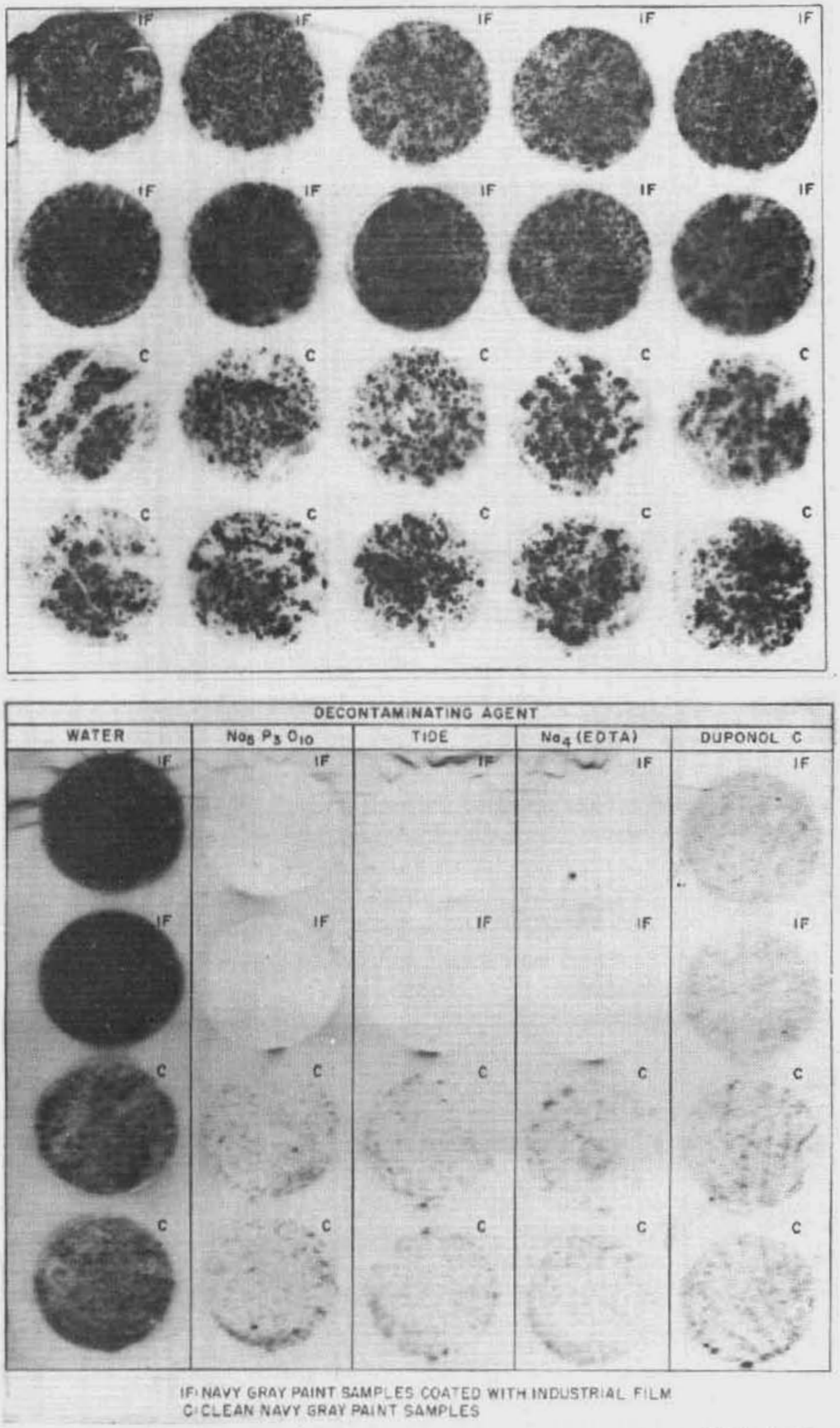


Fig. 8.17 Autoradiographs of Clean and Soiled Navy Gray Paint Samples before and after Decontamination

TABLE 8.10

One-minute Decontamination of Navy Gray Paint

	$\frac{\text{Activity Remaining after 1-min Decontamination by Water}}{\text{Activity Remaining after 1-min Decontamination by Additive}}$					
	Decontamination in Distilled Water at 25°C				Decontamination in Synthetic Sea Water at 25°C	Decontamination in Synthetic Sea Water at 75°C
Decontaminating Agent	Clean Samples from Station 10(a)	Clean Samples from Station 13(b)	Industrial-filmed Samples from Station 10(a)	Industrial-filmed Samples from Station 13(b)	Clean Samples from Station 9(a)	Clean Samples from Station 13(a)
Na_4(EDTA)(c)	3.3	3.7	40	10	1.2	1.8
Tide	4.8	4.7	42	11	2.5	2.5
$Na_5P_3O_{10}$(c)	3.7	3.5	46	8	2.3	3.0
Duponol C	2.1	3.0	6.8	4.7	1.7	1.0
Brij-35					3.9	2.1

(a) Two samples were used in each determination.

(b) Four samples were used in each determination.

(c) Na_4(EDTA) indicates tetrasodium ethylenediaminetetraacetate; $Na_5P_3O_{10}$ designates sodium tripolyphosphate.

5. Water did not visibly remove industrial film, whereas Duponol C partially removed it; tetrasodium ethylenediaminetetraacetate, Tide, and sodium tripolyphosphate seemed to completely remove the film. Apparently, the removal of the industrial film results in decontamination.

Comparisons were made of the activities on surfaces facing towards and facing away from ground zero. Results were quite random, leading to the conclusion that no significant portion of the contaminant approached the samples with a horizontal motion in one direction. A similar inference was made in the study of Sec. 8.4.1.

Sponge decontamination effected a greater percentage decontamination of horizontal surfaces than of vertical surfaces. This is true except in the case of glass, where no comparison may be made, as decontamination was essentially 100 per cent.

For the most part, the greater sponge decontaminability of horizontal surfaces was due to (1) the large activity deposits on the horizontal surfaces, as compared to the vertical surfaces, and (2) the manner in which the large contaminant deposits rested on the horizontal surfaces. A large fraction of the horizontal contamination consisted of loosely held matter, some of which did not even touch the surface. In decontamination, the sponge made intimate contact under water, with the surface, and easily removed these loose layers of contamination.

Wet sponge decontamination was more effective with glass than with the other materials. Results obtained with dry decontamination techniques were similar (cf. Table 8.11). A greater percentage decontamination was achieved with Navy gray paint exposed in the horizontal position than with stainless steel, anodized aluminum, and paint exposed in the vertical position. As explained above, this high decontaminability is felt to be a function of the large initial contamination of the paint.

TABLE 8.11

Wet and Dry Decontamination of Four Materials

Material	Position during and after Contamination	Number of Samples	Average Initial Contamination (c/m x 10^{-4})	Average Contamination Remaining (per cent)
SPONGE DECONTAMINATION				
Navy Gray Paint	Horizontal Vertical	27 26	107 4.2	0.8 3.4
Stainless Steel	Horizontal Vertical	26 24	25.5 2.3	2.0 3.0
Anodized Aluminum	Horizontal Vertical	27 26	38.4 2.6	1.8 3.3
Glass	Horizontal Vertical	26 21	77.0 2.2	0.1 0.0
DRY BRUSH DECONTAMINATION				
Navy Gray Paint	Horizontal Vertical	17 18	48.2 4.4	8.2 12.2
Stainless Steel	Horizontal Vertical	16 17	4.6 3.0	37.4 18.9
Anodized Aluminum	Horizontal Vertical	16 17	5.8 2.3	11 7.2
Glass	Horizontal Vertical	17 12	11.2 4.1	2.2 2.0

8.4.5 Contamination-decontamination Behavior of Selected Commercially Available Materials

The data of this study were examined to determine the contamination and decontamination characteristics of the four experimental materials. Consideration was given to both angular orientation of the materials at the time of the contaminating event and to their position with respect to surface zero.

Each exposure station received varying gross amounts of contamination. Therefore, to compare contamination of materials at different stations, the total activity of all the samples on each plate was normalized.

The same order of material contamination was found with horizontal and with vertical plates; the sequence, in order of increasing contamination, was stainless steel, anodized aluminum, glass, and Navy gray paint. However, the validity of the contamination sequence is doubtful due to the small contamination differences observed. Only Navy gray paint showed an appreciable difference in contamination; this was true with both horizontal and vertical positions. As shown in Fig. 8.18 no fixed ratio of horizontal to vertical activity was found. Figure 8.18 does indicate (as does the work of Sec. 8.4.1) that, almost without exception, horizontal surfaces were more highly contaminated than adjacent vertical surfaces. It appears that as the gross amount of contamination increases, the ratio of activity on the horizontal to the activity on the vertical also increases.

Although a greater percentage decontamination was accomplished with horizontal samples, a greater residual contamination was present on these samples. With the materials, Navy gray paint, stainless steel, and anodized aluminum, the horizontal residual contamination exceeded the vertical residual contamination by factors of approximately six, seven, and eight.

Dry brushing was not as effective in decontamination as the wet sponge technique. However, there were certain similarities in results obtained by the two decontamination methods. Both methods left a smaller percentage residual activity on glass than on the other materials. In both procedures, the percentage decontamination of the horizontal Navy gray paint was better than the percentage decontamination obtainable on stainless steel, anodized aluminum, and Navy gray paint exposed in the vertical position. Note the large initial contamination of the horizontal Navy gray paint. A difference between methods is seen in the fact that with dry techniques the horizontal surfaces, except in the case of the paint, did not decontaminate better than the vertical surfaces.

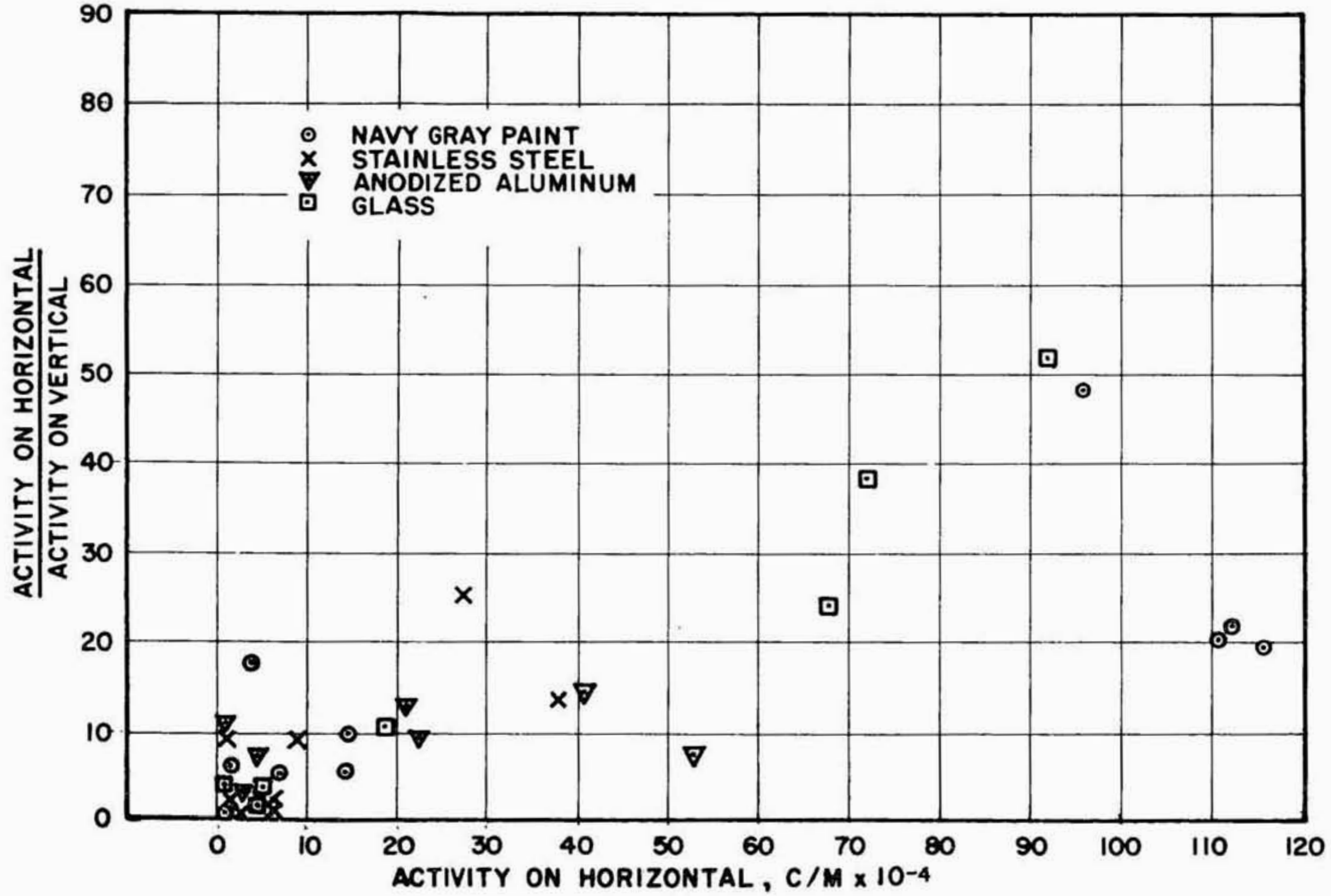


Fig. 8.18 Comparison of Horizontal to Vertical Surface Contamination Ratios for Selected Materials

8.4.6 Investigation of Decontamination Agents

Decontamination, by the immersion and stirring technique of (1) clean Navy gray paint with fresh water additive solutions, and (2) clean Navy gray paint and clean Alclad aluminum with synthetic sea water additive solutions, indicated that most of the Operation JANGLE contaminant was removed in one minute. From counting data on these samples calculations of the ratio of 1-min decontamination by water (salt or fresh) to the 1-min decontamination with an additive (in salt or fresh water) were made. These ratios are summarized in Tables 8.10 and 8.12. A ratio greater than unity indicates the extent to which water leaves a greater amount of activity on samples compared to an additive.

TABLE 8.12

One-minute Decontamination of Alclad Aluminum

Decontaminating Agent	$\frac{\text{Activity Remaining after 1-min Decontamination by Water}}{\text{Activity Remaining after 1-min Decontamination by Additive}}$	
	Decontamination in Synthetic Sea Water at 25°C(a)	Decontamination in Synthetic Sea Water at 75°C(a)
Na_4(EDTA)(b)	0.8	0.4
Tide	1.7	0.8
$Na_5P_3O_{10}$(b)	0.8	1.4
Duponol C	1.7	0.7
Brij-35	2.3	2.4

(a) Two samples were used in each determination.

(b) Na_4(EDTA) indicates tetrasodium ethylenediaminetetraacetate; $Na_5P_3O_{10}$ designates sodium tripolyphosphate.

After the first minute of decontamination, repeated decontamination with the same fresh or salt water decontaminant did not materially decrease the amount of contamination.

8.5 CONCLUSIONS

It was determined that the structural orientation of a surface did influence surface contaminability to varying degrees. It was observed that the amount of contaminant deposited on horizontal surfaces was frequently greater than the amount deposited on non-horizontal surfaces.

Differences of a factor of 30 to 40 were noted. This information is considered to be important with regard to military construction for radiological defense.

While vertical surfaces retained a smaller average particle size than either horizontal or inclined surfaces, the differences between the average size of particles retained at any of the orientations was not great.

No firm conclusions could be drawn with regard to the relationship between surface roughness and contaminability. Surface roughness did have a decided effect on decontaminability. Decontaminability varied by factors of 6 to 10 (residual activity), the rough surfaces retaining more contamination than the smooth. Soft surfaces were more contaminable than hard surfaces (factors of 1.5 to 10) and retained 2 to 3 times more activity, after decontamination, than hard surfaces.

Deliberately soiled surfaces were more contaminable than clean surfaces by factors of 2 to 7.5, but decontaminated as well as or better than clean surfaces.

Navy gray paint was found to be from 1.5 to 12 times more contaminable than bare aluminum, chromium-nickel steel, and glass. All of these materials were decontaminated readily.

The chemical additives used in the immersion techniques for decontamination proved to be advantageous, particularly in treating the soiled surfaces.

CHAPTER 9

TEST OF MATERIALS

Gerald Smith

9.1 ABSTRACT

This report describes an investigation of the possible relationships between the radiological contamination-decontamination characteristics of materials in common military use and the physical properties of their surfaces. The sample materials (prepared by the U. S. Army Chemical Center, Army Field Forces, Corps of Engineers, and Signal Corps) were exposed, horizontally, to the solid particulate fall-out from the Underground Shot.

Analysis of the data obtained led to the conclusion that surface roughness, porosity, and contact angle were of practical importance in evaluating the contamination-decontamination characteristics of materials with respect to dry, solid particulate contamination. It was noted that the magnitude of the effects of these parameters may vary with soil type and condition. Limited investigation of this variability is recommended, and extensive study of surface parameters with respect to wet aerosols is deemed advisable.

9.2 OBJECTIVES

The tests conducted had the following objectives:

1. To determine the validity of results obtained in analogous tests at Operation GREENHOUSE.

2. To establish the merits of roughness, porosity, contact angle, and surface reactivity as criteria for determining the behavior of surfaces exposed to radiological contamination.

3. To measure, evaluate, and compare the surface contamination resulting from a surface burst and an underground burst.

4. To compare the contamination characteristics of various wood surfaces.

5. To assess the contamination-decontamination characteristics of materials submitted by the Corps of Engineers, the Army Field Forces, and the Signal Corps.

9.3 PROCEDURE

For the Surface Shot, all test materials were exposed at a single station which, unfortunately, did not lie within the fall-out area. For the Underground Shot, the test materials were distributed among 7 stations grouped around ground zero as shown in Fig. 9.1. The distribution was made in such a way that regardless of variation from the anticipated fall-out pattern, a sufficient number of samples of each material would be contaminated to provide an adequate base for statistical analysis.

All test surfaces, with two exceptions, were 11-by-11-in. squares. The Army Field Forces submitted 10-by-10-in. samples, and the surfaces used to test the effects of the chemical properties of materials on their contamination-decontamination behavior (hereinafter called Chemistry Panels) were cut as circles 3.4 to 4 in. in diameter.

All test materials were mounted with Pliobond on 1-ft-sq rigid metal panels. The panels were laid horizontally on latticework platforms 2 to 5 ft above the ground at each station, as shown in Fig. 9.2.

Each test surface, with the exception of the wood series, represented a combination of one of three grades of surface roughness, porosity, and contact angle, and one of two grades of retentivity.

Roughness grades of low, medium, and high were determined by visual inspection in all but the Chemistry Panels on which roughness was measured with a profilometer.

Porosity grades of low, medium, and high were determined from the amount of water remaining on a test surface after evacuation of the entrapped air from the pores.

Contact angles of low, medium, and high were determined by optical measurement of the angle subtended by a drop of distilled water at the junction of the air-water interface and the surface of the test material.

The retentivity or nonretentivity of the test surfaces was established from measurements of the fluorescent intensity of a dye adsorbed on the surface.[1]

Details on the materials used in the six different types of panels are provided below.

9.3.1 GREENHOUSE-type Panels

These panels, as the name implies, were prepared to resemble as closely as possible the panels used in a similar test at Operation GREENHOUSE. The materials used in these panels are described in Table 9.1.

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[1] National Bureau of Standards Report (to be published).
Operation GREENHOUSE Report, Project 6.7 (to be published).
National Bureau of Standards Report, No. 6A-103.

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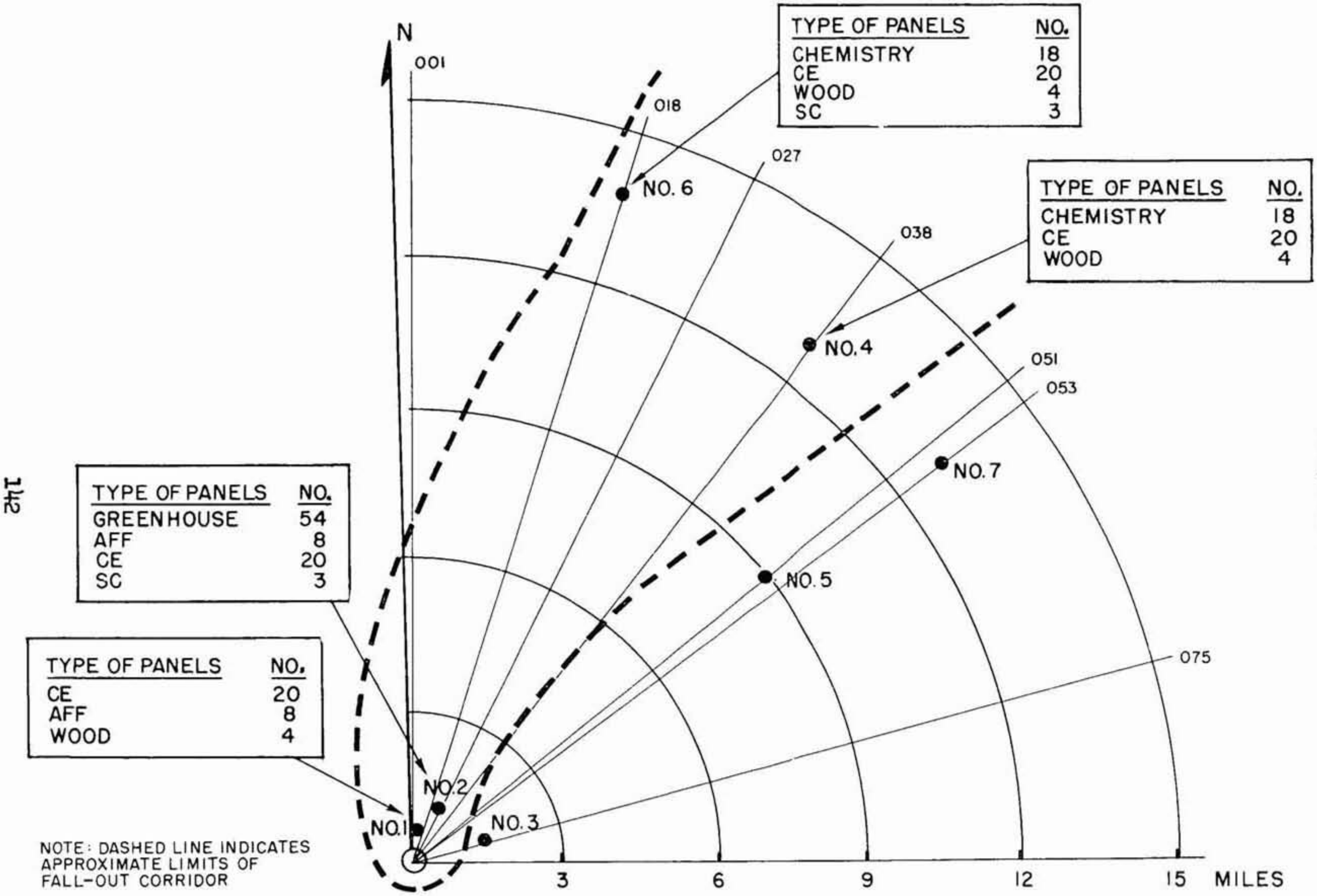

Fig. 9.1 Station Layout and Panel Distribution for the Underground Shot

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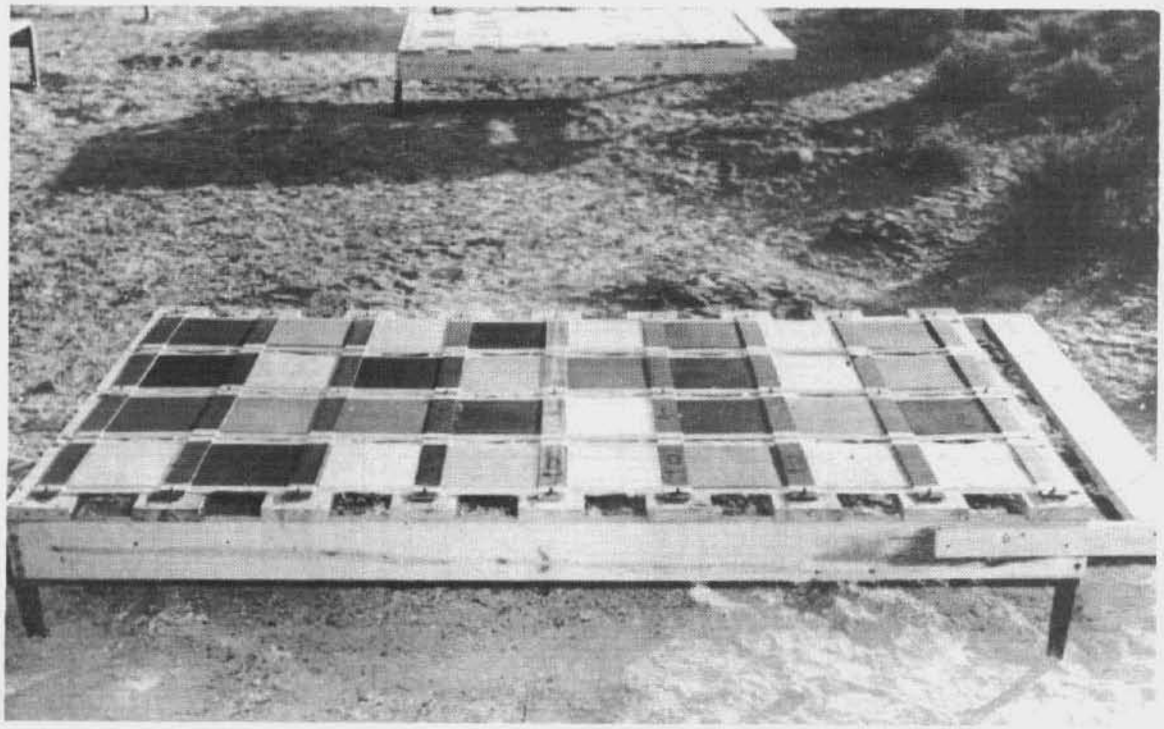

Fig. 9.2 Typical Exposure Platform
with Panels Mounted

9.3.2 Chemistry Panels

Each set of Chemistry Panels included 5 samples each of glass, polystyrene, and stainless steel, and 2 samples of porcelain enamel (Mirawal). The samples in each set exhibited three grades of roughness and two grades of porosity. These surfaces were tested in order to determine the relative effects of physical surface properties and the chemical composition of materials on their contamination-decontamination behavior.

9.3.3 Wood Panels

The wood panels were prepared from bare yellow pine, maple, basswood, and oak. The selection of woods included soft, hard, resinous, and non-resinous characteristics. The wood study was undertaken as a check on the results of tests on these materials during Operation GREENHOUSE.

9.3.4 Corps of Engineers (CE), Army Field Forces (AFF), and Signal Corps (SC) Panels

These panels, hereinafter referred to as CE, AFF and SC Panels respectively, were made up of representative samples of building materials and coatings submitted by the three services. The materials used in the CE and AFF Panels are described in Tables 9.2 and 9.3. All SC Panels consisted of OD paint, per Army Spec. 3-174, Semi-gloss finish, over a primer coat per AN-P-656 Spec.

TABLE 9.1

GREENHOUSE-type Panel Materials

Retentivity and Contact Angle		Low Porosity Materials			Medium Porosity Materials			High Porosity Materials		
		Roughness			Roughness			Roughness		
		Low	Medium	High	Low	Medium	High	Low	Medium	High
Nonretentive Contact Angle	Low	Mirawal (porcelain enamel on steel, glossy finish)			Du Pont Varnish No. 7 (dull finish)			OD Paint on Plywood--TT-E-485b		Glass Cloth
	Medium	Methyl Methacrylate (Lucite)			Clear Metal Lacquer (Co-loidal-ac)			Linoleum (factory finish)	Transite (cement asbestos board)	
	High	Al (aluminum) Soft, 248			Asphalt Varnish (Rubberoid Corp.)			Linoleum (paraffin coated)	Asphalt-Saturated Felt Roofing	Air Force Overcoat Wool
Retentive Contact Angle	Low	Porcelain Metal Enamel (dull finish)			Satinspread (interior) paint, Aqueous Resin)			Fir Plywood		
	Medium	Navy Cocoon 52-C-44 (strippable coating)			OD Paint TT-E-485b			Linoleum (benzene-washed to remove factory finish)		
	High	Goodyear Gray Rubber Tile No. 503			Dixon's Exterior Graphite Paint			Leather (low contact angle)		Canvas Ducking

TABLE 9.2

Corps of Engineers Panel Materials

Code Marking	Description of Material
E-1	Fire-retardant paint. Two coats of VV20 prepared by Vita Var Corporation, Newark, N. J., under a research contract with ERDL.
E-2	Epichlorhydrin resin paint. Two coats of Devran No. K5925 pigmented similar to TT-E-485b, prepared by Devoe Reynolds Company. Panels baked 30 min at 250 F.
E-3	Vinyl-type paint system. One coat Amercoat 23 prime coat; two coats Amercoat 23 body coat; two coats Amercoat 23 seal coat.

TABLE 9.2 (Continued)

Corps of Engineers Panel Materials .

Code Marking	Description of Material
E-4	Alkyd-type paint system. One coat wash primer Mil-P-15328; one coat primer TT-E-485b; one coat lusterless enamel 3-173.
E-5	Phenolic-type paint system. One coat wash primer Mil-P-15328; one coat phenolic primer 3-193, Type I; one coat lusterless enamel 3-194.
E-6	Moisture-vaporproof barrier, conforming to Spec. Mil-B-131A.
E-7	Ethyl cellulose film, conforming to Spec. Mil-P-149, Type I.
E-8	Acetate butyrate, conforming to Spec. Mil-P-149, Type II.
E-9	Cocoon, conforming to Spec. Mil-C-3254.
E-10	P-1, conforming to Spec. Mil-C-6708.
E-11	Dipcoat seal, conforming to Spec. JAN-P-115.
E-12	8-oz cotton duck coated with 0.012 in. natural (GN) rubber.
E-13	8-oz cotton duck coated with 0.008 in. Neoprene (GN) rubber.
E-14	8-oz cotton duck coated with 0.016 in. butyl rubber.
E-15	8-oz cotton duck coated with 0.016 in. standard GRS rubber.
E-16	Polyester resin and Polystyrene laminate bonded to a glass-fiber mat. The laminate was produced by Allied Synthetics Company, San Diego, Calif.
E-17	Three layers of H-643 polyester bonded glass-fiber mat laminated with a polyester resin. The resin is Atlas G-393.
E-18	Cast sheet of MR28V containing 25 per cent calcium carbonate. The resin is produced by Marco Chemical Company, Sewaren, N. J.
E-19	Vinyl chloride polymer plastisol XC230, produced by Stoner Mudge, Inc.
E-20	Methyl methacrylate, manufactured by Rohm and Hass.

TABLE 9.3

Army Field Forces Panel Materials

Panel No.	Material and Surface Finish	Panel No.	Material and Surface Finish
F-1	Steel, cold rolled, auto. Grade I, per JAN-C-490 Primer, per Fed. TT-P-636 Semi-Gloss, OD Grade I, Class A, per Army 3-174	F-5	Steel, cold rolled, auto. Grade I, per JAN-C-490 Primer, per Fed. TT-P-636 Wrinkle, OD Enamel, Type I or II, per Army 3-188
F-2	Steel, cold rolled, auto. Grade I, per JAN-C-490 Primer, per Fed. TT-P-636 Semi-Gloss, OD Grade I, Class B, per Army 3-174	F-6	Aluminum, Alloy-24ST Annodized, per AN-QQ-A-696 Primer, per MIL-P-6889 Semi-Gloss, OD Enamel, Grade I, Class B, per Army Spec. 3-174
F-3	Steel, cold rolled, auto. Grade I, per JAN-C-490 Primer per Fed. TT-P-636 Gloss, OD Enamel, Class A, per Fed. Spec. TT-E-489	F-7	Magnesium Alloy - FS Type III treatment, per AN-M-12, Primer, per MIL-P-6889, Semi-Gloss, OD Enamel, Grade I, Class B, per Army Spec. 3-174
F-4	Steel, cold rolled, auto. Grade I, per JAN-C-490 Primer, per Fed. TT-P-636 Gloss, OD Enamel, Class B, per Fed. Spec. TT-E-489	F-8	Magnesium Alloy - M Type II treatment, per AN-M-12, Primer, per MIL-P-6889, Semi-Gloss, OD Enamel, Grade I, Class B, per Army Spec. 3-174

9.3.5 Panel Recovery and Investigations at the Site

The panels at Station Nos. 2, 4, and 6 were recovered 1 day after the Underground Shot; those at Station No. 1 were recovered 2 days after the Shot. Station Nos. 3, 5, and 7 lay outside the fall-out area, as shown in Fig. 9.1.

The contaminated panels were placed horizontally on individual shelves in wooden boxes and transported to a shielded storage area near the base camp laboratory. Before processing, the panels were inverted over a collecting can to remove any very loosely held contamination which would have presented a serious hazard to the laboratory facilities.

Activity counts were made on all panels, using a scintillation counter. Each panel was then vacuumed, using a Spencer industrial vacuum cleaner fitted with a 15-in. sweeper head. Two passes in opposite directions were made across each panel. The panels were recounted, and representative samples were photographed and autoradiographed.

9.3.6 Investigations at Army Chemical Center (ACC)

The panels from Stations 4 and 6 were flown to ACC on the fourth day, and the panels from Stations 1 and 2 on the ninth day after the Underground Shot.

Processing and investigation were undertaken in two distinct phases. In the first phase, an activity count was made on each panel. Each panel was then subjected to 2 passes by either a wet brushing machine or a spraying machine employing various decontamination solutions. The panels were then recounted.

In the second phase the panels were sprayed and scrubbed by machine and by hand until each had reached a constant radiation level. A final activity count and autoradiographs were made, and contaminant penetration was studied with the aid of a microtome.

The data obtained were corrected for decay, background, coincidence (where necessary), and instrument variations. Data obtained at the test site were corrected to the common base of U + 30 hr, while ACC data were corrected to the common base of U + 120 hr using the $t^{-1.2}$ decay curve.

The site and ACC data were analyzed separately, the following statistical techniques being used for evaluation:

1. GREENHOUSE-type panels by analysis of variance for a randomized block.[2]

2. Chemistry panels by the Sign Test, and by Snedecor's "F" Test, when applicable.[3]

3. All other panels by Rank Correlation and combinations of the techniques mentioned under footnote 2.[4]

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[2] Kenney and Keeping, Mathematics of Statistics, D. Van Nostrand.

[3] Dixon and Massey, Statistical Analysis, McGraw Hill.

[4] Johnson, Statistical Methods in Research, Prentice-Hall.

9.4 RESULTS AND DISCUSSION

Listed below are the station numbers and general gamma field intensities of the four contaminated stations at the times the panels were recovered.

Station No.	Intensity	Time (days)
1	2.5 r/hr	U + 2
2	3.0 r/hr	U + 1
4	200.0 mr/hr	U + 1
6	40.0 mr/hr	U + 1

The data, analysis, and discussion for each of the six types of panels exposed are grouped under individual headings below.

9.4.1 GREENHOUSE-type Panels

Site and ACC data on the GREENHOUSE-type Panels are presented in Table 9.4. The analysis and comparison of these data with the Operation GREENHOUSE results are given in Tables 9.5 and 9.6. The results of the statistical analyses were normalized to unity to make the trends more readily discernible. A study of these tables indicated the following:

1. Roughness generally showed strong trends of high statistical reliability. Contamination and resistance to decontamination increased with surface roughness.

2. Porosity showed trends of variable and generally low statistical reliability. These trends were not as clear-cut as those for roughness, and tended to be noncontinuous. Nevertheless, it appeared that contaminability and resistance to decontamination increased with porosity.

3. Contact angles gave statistically significant trends. Surfaces having low contact angles (hydrophilic surfaces) retained more contamination, and decontaminated less readily than those with high contact angles.

4. Dye retentivity gave trends of fair reliability but modest proportions. Retentive surfaces decontaminated less readily than nonretentive surfaces.

These results show that smooth, nonporous, hydrophobic, and nonretentive surfaces were easier to decontaminate than surfaces with the opposite properties. These parameters, with the exception of dye retentivity, gave trends of considerable proportions, and consequently merit consideration in radiological contamination-decontamination problems.

TABLE 9.4
GREENHOUSE-type Panels, Site and ACC Data

Wettability and Contact Angle		Contam (area) (c/m)	SITE DATA (a)			ACC DATA (b)		
			Low Porosity Materials					
			Roughness					
			Low	Medium	High	Low	Medium	High
Nonretentive Contact Angle	Low		MIRAWAL					
		initial	92,000	337,145	2,078,007	13,231	49,213	1,400,703
		residual	29,904	60,092	No Data	931	6,448	No Data
		% residual	34.5	17.8	*	7.0	13.1	*
	Medium		METHYL METHACRYLATE (LUCITE)					
		initial	131,042	214,894	306,707	84,316	176,680	92,429
		residual	79,825	125,580	60,170	764	1,429	644
		% residual	60.9	58.4	19.6	0.9	0.8	0.7
	High		ALUMINUM					
		initial	46,016	135,135	463,216	20,333	122,142	340,623
		residual	19,602	84,932	290,245	2,116	2,610	2,926
		% residual	42.6	62.8	62.6	10.4	2.1	0.2
Retentive Contact Angle	Low		PORCELAIN					
		initial	No Data	No Data	No Data	No Data	No Data	No Data
		residual	*	*	*	*	*	*
		% residual	*	*	*	*	*	*
	Medium		NAVY COCOON					
		initial	283,303	439,868	343,158	309,651	470,422	365,123
		residual	202,143	425,125	270,741	12,602	5,015	27,456
		% residual	71.4	96.6	78.9	4.1	1.1	7.5
	High		GOODYEAR GRAY RUBBER TILE					
		initial	346,055	265,555	285,197	300,118	116,852	214,838
		residual	295,668	81,246	249,473	1,493	4,634	7,584
		% residual	85.4	30.6	87.5	0.5	4.0	3.5

Wettability and Contact Angle		Contam (area) (c/m)	SITE DATA			ACC DATA		
			Medium Porosity Materials					
			Roughness					
			Low	Medium	High	Low	Medium	High
Nonretentive Contact Angle	Low		DU PONT VARNISH					
		initial	246,388	349,853	399,004	171,885	327,764	300,763
		residual	No Data	253,821	255,631	2,771	4,163	9,171
		% residual	*	72.6	64.1	1.6	1.3	3.0
	Medium		CLEAR METAL LACQUER					
		initial	263,500	315,028	429,079	117,141	100,722	166,733
		residual	No Data	283,691	338,160	102	1,010	441
		% residual	*	90.0	78.8	0.1	1.0	0.3
	High		RUBBEROID CORP ASPHALT VARNISH					
		initial	324,177	134,424	275,306	117,141	100,722	166,733
		residual	133,707	71,996	127,275	102	1,010	441
		% residual	41.2	53.6	46.2	0.1	1.0	0.3
Retentive Contact Angle	Low		SATINSPREAD					
		initial	201,906	319,528	412,493	1,290,745	214,250	178,540
		residual	No Data	142,487	344,070	No Data	5,760	13,584
		% residual	*	44.6	83.4	*	2.7	7.6
	Medium		OD PAINT					
		initial	161,139	413,763	319,837	90,658	286,199	252,373
		residual	59,793	231,294	199,347	633	1,343	2,301
		% residual	37.1	55.9	62.3	0.7	0.5	0.9
	High		DIXON'S EXTERIOR GRAPHITE					
		initial	197,945	272,282	303,450	125,426	167,288	243,284
		residual	91,686	111,170	171,240	1,768	1,070	2,206
		% residual	46.3	40.8	56.4	1.4	0.6	0.9

Wettability and Contact Angle		Contam (area) (c/m)	SITE DATA			ACC DATA		
			High Porosity Materials					
			Roughness					
			Low	Medium	High	Low	Medium	High
Nonretentive Contact Angle	Low		OD PAINT					
		initial	No Data	No Data	530,921	No Data	No Data	278,974
		residual	*	*	255,690	*	*	35,166
		% residual	*	*	48.2	*	*	12.6
	Medium		LINOLEUM (FAC. FIN.)	TRANSITE		LINOLEUM (FAC. FIN.)	TRANSITE	
		initial	379,960	No Data	No Data	274,026	No Data	No Data
		residual	322,782	*	*	493	*	*
		% residual	85.0	*	*	0.2	*	*
	High		LINOLEUM (PARAFFIN)	ASPHALT FELT	USAF WOOL COAT	LINOLEUM (PARAFFIN)	ASPHALT FELT	USAF WOOL COAT
		initial	165,839	286,922	1,239,470	173,981	195,705	524,997
		residual	128,727	183,159	1,147,149	376	7,524	98,254
		% residual	78.6	63.8	92.6	0.2	3.8	18.7
Retentive Contact Angle	Low		FIR PLYWOOD					
		initial	276,906	301,416	283,810	383,977	381,460	365,320
		residual	258,327	236,470	266,958	19,877	24,836	26,045
		% residual	93.3	78.4	94.1	4.2	6.5	7.1
	Medium		LINOLEUM (FINISH REMOVED)					
		initial	355,091	251,689	246,399	212,945	270,970	201,402
		residual	155,057	212,663	150,324	1,807	8,223	3,286
		% residual	43.7	84.5	61.0	0.8	3.0	1.6
	High		LEATHER		CANVAS DUCKING	LEATHER		CANVAS DUCKING
		initial	No Data	No Data	491,626	No Data	No Data	94,414
		residual	*	*	69,632	*	*	16,542
		% residual	*	*	14.2	*	*	17.5

(a) All panels vacuumed
(b) All panels brushed with 1% Versene solution

TABLE 9.5

Statistical Analysis, GREENHOUSE-type Panels

Parameter	Test	Initial Contamination Low	Medium	High	PL(a)	Residual Contamination (after 1st phase decon.) Low	Medium	High	PL
Roughness	Site Data, JANGLE	1.00	1.23	1.56	S	1.00	1.21	1.47	PS
	ACC Data, JANGLE	1.00	1.45	1.67	S	1.00	1.42	4.05	VS
	Operation GREENHOUSE	1.00	1.27	1.95	S	1.00	1.36	2.11	VS
Porosity	Site Data, JANGLE	1.00	1.15	1.23	PS	1.00	1.16	1.25	PS
	ACC Data, JANGLE	1.44	1.00	1.46	NS	1.86	1.00	4.49	VS(b)
	Operation GREENHOUSE	1.00	1.00	1.21	PS	1.00	1.12	1.28	PS
Contact Angle	Site Data, JANGLE	1.21	1.14	1.00	PS(c)	1.50	1.48	1.00	S
	ACC Data, JANGLE	1.45	1.47	1.00	S(b)	3.87	1.24	1.00	S
	Operation GREENHOUSE	1.00	1.07	1.00	NS	1.00	1.11	1.16	NS
		Retentive	Nonretentive		PL	Retentive	Nonretentive		PL
Retentivity	Site Data, JANGLE	1.13	1.00		NS	1.23-	1.00		PS
	ACC Data, JANGLE	1.07	1.00		NS	1.23	1.00		VS
	Operation GREENHOUSE	1.25	1.00		S	1.41	1.00		S

(a) Probability Level.

(b) Very significant for Medium < High and Low < High, but not for Low > Medium.

(c) Significant for High > Medium and High > Low, but not for Medium > Low.

TABLE 9.6

Second Phase Decontamination of GREENHOUSE-type Panels (Summary)

Surface Parameter(a)	Low	Medium	High
Roughness	1.00	1.44	1.71
Porosity	1.10	1.00	2.93
Contact Angle	4.56	1.00	1.57

(a) Retentive: 2.00
Nonretentive: 1.00

In comparing Operation JANGLE results with Operation GREENHOUSE results, it was noted that, with the exception of contact angle, qualitative agreement existed. However, since the contact angle trends for Operation GREENHOUSE were not statistically significant, no importance was attached to this slight divergence.

Operation JANGLE trends for the surface parameters were generally much more pronounced than those for Operation GREENHOUSE. This may indicate that the magnitude of surface parameter trends is variable for different types of contaminating events. (At Operation GREENHOUSE, the panels were exposed on the wings of drone aircraft flown through the cloud produced by a tower shot.) The agreement in the results of the two operations, despite the difference in the type of contaminating event, not only strengthens their reliability, but may indicate that the findings are generally applicable to contaminating events involving relatively dry aerosols.

9.4.2 Chemistry Panels

Site and ACC data on the Chemistry Panels are presented in Tables 9.7 and 9.8. The results of the statistical analysis of these data are given in Table 9.9. A study of these tables indicated the following:

1. No significant or consistent variations were noted for similar surfaces prepared from the four chemically unlike materials. These findings are not conclusive, but seem to indicate that the contaminability-decontaminability of these materials were not sensitive to their chemical differences.

2. Roughness showed significant trends similar to those obtained from the GREENHOUSE-type Panels.

3. Porosity trends for site data and the first phase of decontamination at ACC were generally not significant, but where statistical significance was indicated, the trends agreed with those noted for the GREENHOUSE-type Panels. Second phase decontamination, however, brought to light strong porosity trends indicating that coarse-pored surfaces (maximum pore size 40 μ) were more difficult to decontaminate than fine-pored surfaces (maximum pore size 5 μ).

In general, the results from the Chemistry Panels indicated that the differences in their chemical composition, insofar as they did not affect their physical surface properties, had little or no effect on the contaminability-decontaminability of the materials.

TABLE 9.7

Roughness Study, Chemistry Panels

Material and Contamination Level (c/m)	Station No. 4			Station No. 6		
	Smooth	Rough	Very Rough	Smooth	Rough	Very Rough
	SITE DATA[a]					
Glass						
Initial	28, 170	88, 441	46, 642	13, 140	28, 121	25, 186
Residual	22, 350	68, 163	33, 075	11, 144	19, 187	18, 430
% Residual	79. 3	77. 1	70. 9	84. 8	68. 2	73. 2
Polystyrene						
Initial	84, 025	91, 300	88, 573	31, 392	16, 950	25, 564
Residual	49, 972	62, 652	61, 197	16, 745	15, 111	19, 945
% Residual	59. 5	68. 6	69. 1	53. 3	89. 2	88. 0
Steel						
Initial	99, 329	106, 595	88, 802	27, 067	No data	30, 584
Residual	51, 983	69, 211	65, 473	9, 088	20, 695	21, 642
% Residual	52. 3	64. 9	73. 7	33. 6		70. 8
Mirawal						
Initial	95, 386	97, 194	69, 485	9, 269	15, 299	No data
Residual	58, 664	69, 252	49, 270	6, 724	12, 382	23, 588
% Residual	61. 5	71. 2	70. 9	72. 5	80. 9	-
	ACC DATA[b]					
Glass						
Initial	35, 096	110, 388	50, 388	12, 695	15, 544	20, 876
Residual	855	2, 270	2, 603	80	648	767
% Residual	2. 4	2. 1	5. 2	0. 6	4. 2	3. 7
Polystyrene						
Initial	66, 497	84, 324	28, 961	17, 974	26, 314	24, 687
Residual	1, 094	2, 740	6, 397	105	228	895
% Residual	1. 6	3. 2	22. 1	0. 6	0. 9	3. 6
Steel						
Initial	64, 362	95, 023	98, 628	6, 825	26, 866	27, 609
Residual	2, 178	4, 399	6, 400	256	990	1, 388
% Residual	3. 4	4. 6	6. 5	3. 8	3. 7	5. 0
Mirawal						
Initial	87, 670	123, 384	83, 987	8, 767	16, 270	29, 795
Residual	1, 820	2, 385	2, 064	335	440	553
% Residual	2. 1	1. 9	2. 5	3. 8	2. 7	1. 9

(a) Materials at Stations Nos. 4 and 6 vacuumed.

(b) Materials at Station No. 4 sprayed with water.
Materials at Station No. 6 brushed with 1 per cent Versene solution.

TABLE 9.8

Porosity Study, Chemistry Panels

Material and Contamination Level (c/m)	Station No. 4		Station No. 6	
	Fine Pores	Coarse Pores	Fine Pores	Coarse Pores
SITE DATA[a]				
Glass				
Initial	11,295	17,532	3,527	7,439
Residual	3,928	6,468	1,275	2,139
% Residual	34.8	36.9	36.1	28.8
Polystyrene				
Initial	20,312	14,280	8,063	3,157
Residual	4,595	5,257	2,348	1,895
% Residual	22.6	36.8	29.1	60.0
Steel				
Initial	11,979	22,884	5,071	5,319
Residual	3,061	5,560	2,025	1,288
% Residual	25.6	24.3	39.9	24.2
ACC DATA[b]				
Glass				
Initial	5,520	8,668	1,691	2,114
Residual	918	1,913	311	264
% Residual	16.6	22.0	18.4	12.5
Polystyrene				
Initial	4,613	7,163	1,682	1,428
Residual	381	552	217	239
% Residual	8.3	7.7	12.9	16.7
Steel				
Initial	4,589	7,620	2,690	1,245
Residual	169	996	198	91
% Residual	3.7	13.1	7.4	7.3

(a) Materials at Station Nos. 4 and 6 vacuumed.

(b) Materials at Station No. 4 sprayed with water.
Materials at Station No. 6 brushed with 1 per cent Versene solution.

TABLE 9.9

Statistical Analysis, Chemistry Panels

Surface Parameter and Significance		Site Data				ACC Data (1st Stage Decon.)			
		Initial Contam.		Residual Contam.		Initial Contam.		Residual Contam.	
		No. 4	No. 6	No. 4	No. 6	No. 4	No. 6	No. 4	No. 6
Roughness	Low	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Medium	1.30	1.00	1.46	1.54	1.62	1.84	2.00	2.96
	High	1.00	1.33	1.14	1.90	1.03	2.22	2.97	4.62
Probability Level		PS	NS	PS	S	PS	S	S	S
Porosity	Fine Pores	1.00	1.05	1.00	1.06	1.00	1.26	1.00	1.22
	Coarse Pores	1.25	1.00	1.49	1.00	1.59	1.00	2.35	1.00
Probability Level		PS	NS	PS	NS	VS	NS	PS	NS

Second Stage (Total) Decontamination of Chemistry Set			
Roughness		Porosity	
Smooth	Very Rough	Fine Pores	Coarse Pores
1.00	3.68	1.00	3.39

9.4.3 Wood Panels

Site and ACC data for the wood panels are presented in Table 9.10. Rank analysis of the site data failed to show correlation between stations. Rank analysis of the ACC data indicated a very pronounced trend for residual contamination. The woods ranked, in order of decreasing residual contamination, basswood, pine, maple, and oak (normalized averages: 1.84, 1.49, 1.34, and 1.00, respectively). The hard, dense woods decontaminated more readily than the soft, porous woods. As noted at Operation GREENHOUSE, the softer, more porous parts of the wood (the light striations) retained more contamination than the harder, less porous parts (the dark striations).

TABLE 9.10

Wood Panels, Site and ACC Data

Material and Station No.	Initial Contamination (c/m)	Residual Contamination (c/m)	Per Cent Residual Contamination
	SITE DATA[(a)]		
Station No. 1			
Pine	239,726	192,504	80.3
Oak	287,481	216,602	75.3
Basswood	298,236	239,053	80.2

TABLE 9.10 (Continued)

Wood Panels, Site and ACC Data

Material and Station No.	Initial Contamination (c/m)	Residual Contamination (c/m)	Per Cent Residual Contamination
		SITE DATA[a]	
Station No. 1			
Maple	356,952	297,769	83.4
Station No. 4			
Pine	85,752	54,437	63.5
Oak	52,884	25,224	47.7
Basswood	84,479	31,315	37.1
Maple	81,051	18,340	22.6
Station No. 6			
Pine	22,885	16,973	74.2
Oak	24,244	12,981	53.5
Basswood	24,183	18,078	74.8
Maple	23,399	10,864	46.4
		ACC DATA[b]	
Station No. 1			
Pine	191,620	34,059	17.8
Oak	158,210	25,687	16.2
Basswood	189,594	34,562	18.2
Maple	238,884	31,874	13.3
Station No. 4			
Pine	52,537	13,276	25.0
Oak	33,101	7,474	23.0
Basswood	60,400	21,267	35.0
Maple	31,964	13,128	41.0
Station No. 6			
Pine	12,216	2,483	20.0
Oak	12,380	1,835	15.0
Basswood	9,429	2,426	26.0
Maple	12,156	1,886	16.0

[a] Material at all stations vacuumed.

[b] Station No. 1 materials brushed with 1 per cent Tide solution.
Station No. 4 materials dry brushed and vacuumed.
Station No. 6 materials brushed with water.

9.4.4 Corps of Engineers Panels

Site and ACC data on the CE Panels are presented in Table 9.11. The results of the analysis of the ACC data are shown in Table 9.12. A study of these tables indicated the following:

1. Concordance analysis of the site data failed to show significant correlation of panel ranks among the four sets for either initial contamination, or residual contamination after vacuuming.

2. Concordance analysis of the ACC data for rank order approached significance for residual contamination. The rank order shown in Table 9.12 did not change significantly after the second phase of decontamination.

3. In general, painted, hard, smooth, and nonporous surfaces were easier to decontaminate than soft, rubbery, fibrous, and porous surfaces.

TABLE 9.11

Site and ACC Data, Corps of Engineers Panels

Panel Number	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual
	SITE DATA, STATION NO. 1[a]			SITE DATA, STATION NO. 2[a]		
E-01	273,460	249,204	91.1	2,089,421	2,108,898	100.0
E-02	354,102	321,311	90.7	1,813,912	1,280,399	70.6
E-03	445,369	409,676	92.0	682,257	458,014	67.1
E-04	315,784	287,479	91.0	352,544	219,614	62.3
E-05	204,340	176,855	86.5	2,127,836	2,068,822	97.2
E-06	854,626	738,803	86.4	513,213	408,529	79.6
E-07	164,646	135,340	82.2	445,131	362,540	81.4
E-08	312,212	290,749	93.1	374,460	287,608	76.8
E-09	364,462	358,024	98.2	396,938	352,529	88.8
E-10	454,548	392,784	86.4	510,093	417,867	81.9
E-11	110,628	102,860	93.0	384,306	284,391	74.0
E-12	67,630	45,206	66.8	367,792	319,440	86.8
E-13	98,145	90,168	91.9	--	No data	--
E-14	483,681	421,814	87.2	312,674	247,922	79.3
E-15	49,273	33,471	67.9	298,346	298,346	39.3
E-16	327,572	303,081	92.5	1,667,369	1,507,576	90.4
E-17	238,075	220,389	92.6	1,871,326	1,700,194	90.8
E-18	2,258,140	1,890,928	83.7	766,953	438,264	57.1
E-19	332 815	317,200	95.3	367,020	257,230	70.1
E-20	158,837	142,218	89.5	1,459,855	1,148,041	78.6

TABLE 9.11 (Continued)

Site and ACC Data, Corps of Engineers Panels

Panel Number	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual
ACC DATA, STATION NO. 1[b]				ACC DATA, STATION NO. 2[b]		
E-01	172,214	No data	--	1,348,596	5,313	0.4
E-02	210,790	2,653	1.2	827,294	3,072	0.4
E-03	282,475	539	0.2	350,579	964	0.3
E-04	249,623	854	0.3	187,322	1,912	1.0
E-05	154,604	2,162	1.4	240,115	3,555	0.3
E-06	415,160	54,038	13.0	252,646	32,881	13.0
E-07	120,887	527	0.4	284,721	3,233	1.1
E-08	249,911	3,978	1.6	245,196	9,809	4.0
E-09	294,710	13,499	4.6	313,323	18,258	5.8
E-10	254,882	3.276	1.3	346,403	24,314	7.0
E-11	--	No data	--	253,170	16,088	6.4
E-12	29,852	3,210	10.8	276,699	6,001	2.2
E-13	48,348	5,267	10.9	--	No data	--
E-14	97,026	5,939	6.1	182,659	9,521	5.2
E-15	25,830	4,357	16.9	104,080	6,568	6.3
E-16	192,623	1,487	0.8	1,146,878	26,276	2.3
E-17	144,874	4,144	2.9	1,269,360	6,800	0.5
E-18	643,855	1,652	0.2	310,021	32,439	10.5
E-19	217,598	4,639	2.1	237,594	24,741	10.4
E-20	119,277	178	0.1	774,441	2,481	0.4
SITE DATA, STATION NO. 4[a]				SITE DATA, STATION NO. 6[a]		
E-01	93,124	66,639	71.6	29,101	22,838	78.5
E-02	97,284	62,675	64.4	30,908	20,568	66.5
E-03	99,858	73,745	73.8	14,618	13,127	89.8
E-04	112,484	65,854	58.5	19,490	17,022	87.3
E-05	90,509	65,848	72.8	37,935	22,923	60.4
E-06	121,552	89,202	73.4	39,970	30,406	76.1
E-07	91,001	73,605	80.9	31,082	22,229	71.5
E-08	84,539	68,390	80.9	26,968	26,722	99.1
E-09	90,519	74,272	82.0	26,274	21,855	83.2
E-10	95,671	70,100	73.3	27,870	24,403	87.6
E-11	88,768	52,200	58.8	26,378	18,070	68.5
E-12	96,978	40,582	41.8	28,826	15,989	55.5
E-13	73,540	52,417	71.3	30,513	13,562	44.4
E-14	94,007	61,332	65.2	--	No data	--
E-15	94,341	21,895	23.2	27,396	17,520	64.0
E-16	74,089	57,589	77.7	24,512	22,281	90.0

TABLE 9.11 (Continued)

Site and ACC Data, Corps of Engineers Panels

Panel Number	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual
	SITE DATA, STATION NO. 4[a]			SITE DATA, STATION NO. 6[a]		
E-17	29,186	22,023	75.4	26,125	17,104	65.5
E-18	81,399	59,355	72.9	29,823	16,741	56.1
E-19	90,175	68,010	75.4	15,887	15,400	96.9
E-20	21,740	17,102	78.7	19,833	18,884	95.2
	ACC DATA, STATION NO. 4[b].			ACC DATA, STATION NO. 6[b]		
E-01	99,107	1,757	1.8	22,783	528	2.3
E-02	99,405	792	0.8	25,826	334	1.3
E-03	103,083	695	0.7	13,846	187	1.4
E-04	100,708	1,045	1.0	13,710	420	3.1
E-05	99,510	901	0.9	16,357	739	4.5
E-06	112,358	11,247	10.0	25,700	9,683	37.7
E-07	101,645	303	0.3	18,711	625	3.3
E-08	112,602	1,305	1.2	27,712	3,105	11.2
E-09	107,674	2,940	2.7	25,022	19,514	88.0
E-10	114,254	12,225	10.7	24,691	2,739	11.1
E-11	68,000	25,148	37.0	--	Surface peeled	--
E-12	56,615	2,473	4.4	13,510	2,943	21.8
E-13	67,804	4,803	7.4	13,377	4,226	31.6
E-14	65,950	8,409	12.7	--	No data	--
E-15	35,160	1,757	5.0	18,420	2,570	24.0
E-16	60,235	968	1.4	--	Surface peeled	--
E-17	67,489	398	1.4	--	No data	--
E-18	93,529	1,258	1.3	14,872	1,049	7.0
E-19	90,671	4,063	4.5	16,344	1,616	9.9
E-20	20,382	193	0.9	19,025	77	0.4

[a] All panels at Stations 1, 2, 4, and 6 were vacuumed.

[b] Panels were decontaminated as follows: at Station Nos. 1 and 6, brushed with 1 per cent Tide solution; at Station No. 2, sprayed with water; at Station No. 4, sprayed with 1 per cent Versene solution.

[redacted]

TABLE 9.12

Ranking of Materials after First Phase Decontamination, Corps of Engineers Panels

Panel	Material	Residual Contamination Indices
E-20	Methyl Methacrylate	1.00
E-03	Vinyl-type Paint	1.80
E-07	Ethyl Cellulose Film	2.87
E-04	Alkyd-type Paint	3.16
E-02	Epichlorhydrin Resin Paint	4.76
E-01	Fire Retardant Paint	5.14
E-05	Phenolic-type Paint	5.41
E-17	Polyester Bonded Glass with Resin	7.76
E-16	Polyester Resin	9.73
E-18	Cast Sheet	11.33
E-15	GRS Rubber on Cotton Duck	13.25
E-12	Natural Rubber on Cotton Duck	13.52
E-08	Acetate Butyrate	14.31
E-19	Vinyl Chloride Plastisol	16.85
E-14	Butyl Rubber on Cotton Duck	20.81
E-10	P-1	25.63
E-13	Neoprene on Cotton Duck	26.21
E-11	Dipcoat Seal	52.87
E-09	Cocoon	65.35
E-06	Moisture Vaporproof Barrier	93.82

9.4.5 Army Field Forces Panels

Site and ACC data for the AFF Panels are presented in Table 9.13. These panels were so similar in their contamination-decontamination behavior that statistical analysis failed to show any significant variations. All the panels decontaminated readily in the first phase (5.5 per cent average residual), and second phase decontamination reduced the count on all panels to background.

TABLE 9.13

Site and ACC Data, Army Field Forces Panels

	Station No. 1			Station No. 2		
Panel Number	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual
SITE DATA[a]						
F-1	313,370	282,600	90.2	771,093	704,566	91.4
F-2	564,544	577,946	>100.0	1,954,780	1,963,975	>100.0
F-3	294,541	270,953	92.0	1,566,572	1,076,310	68.7
F-4	253,878	205,039	80.8	1,328,472	594,683	44.8
F-5	698,585	645,666	92.4	1,310,860	836,706	63.8
F-6	246,002	205,730	83.6	229,364	145,620	63.5
F-7	228,148	198,788	87.1	No data	1,729,322	No data
F-8	232,148	175,060	75.4	1,906,105	1,924,984	>100.0
ACC DATA[b]						
F-1	249,375	1,831	0.7	509,811	2,840	0.6
F-2	342,296	847	0.4	1,321,742	3,055	0.2
F-3	235,164	1,691	0.7	716,549	1,712	0.2
F-4	181,955	562	0.3	397,107	1,434	0.4
F-5	459,813	1,991	0.4	445,577	1,028	0.2
F-6	172,588	829	0.5	144,634	2,752	1.9
F-7	166,345	2,052	1.2	1,057,272	2,095	0.2
F-8	150,018	1,214	0.8	1,215,380	4,808	0.4

(a) Panels at Station Nos. 1 and 2 vacuumed.

(b) Panels at Station No. 1 sprayed with ACC agent; at Station No. 2, water.

9.4.6 Signal Corps Panels

The two sets of three identical panels submitted by the Signal Corps were decontaminated readily by all methods tested as shown in Table 9.14.

TABLE 9.14

Site and ACC Data, Signal Corps Panels

Station Number	Panel Number	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual	Decontamination Procedure
SITE DATA					
2	C-S-1	1,039,701	431,437	41.5	Vacuum
2	C-S-2	838,499	552,932	65.9	Vacuum
2	C-S-3	53,754	42,242	78.6	Vacuum
6	C-U-1	30,483	20,589	67.5	Vacuum
6	C-U-2	27,805	22,356	80.4	Vacuum
6	C-U-3	29,299	21,121	72.1	Vacuum

TABLE 9.14 (Continued)

Site and ACC Data, Signal Corps Panels

Station Number	Panel Number	Initial Level (c/m)	Residual Level (c/m)	Per Cent Residual	Decontamination Procedure
ACC DATA					
2	C-S-1	278,614	1,271	0.4	Spray (water)
2	C-S-2	298,179	367	0.1	Spray (USNRDL agent)
2	C-S-3	44,199	163	0.4	Spray (ACC agent)
6	C-U-1	24,061	1,711	7.1	Brush (1 per cent Tide + Versene)
6	C-U-2	25,306	2,530	10.0	Brush (USNRDL agent)
6	C-U-3	25,089	632	2.5	Brush (ACC agent)

9.4.7 Miscellaneous Observations

It was noted, from autoradiographs made before and after decontamination, that scratches, breaks, and other discontinuities in the panel surfaces tended to collect and retain more contamination than the unmarred portions. Autoradiographs of the wood panels clearly indicated the contaminant distribution mentioned in 9.4.3.

The penetration study made with the aid of a microtome indicated that most of the contaminant could be removed by a slice 20 microns deep. It was noted that wet decontamination methods drove contamination deeper into leather samples, but did not affect the wood samples similarly.

9.5 CONCLUSIONS AND RECOMMENDATIONS

It is concluded that roughness, porosity, contact angle, and dye retentivity are pertinent parameters relative to radiological contamination-decontamination. However, the magnitude of their respective effects is variable, and determined by the specific conditions of the contaminating event.

Of the above-named parameters, only roughness, porosity, and contact angle produce effects of such magnitude as to merit practical consideration (relative to dry particulate contamination, at least) in the qualitative evaluation of the contamination-decontamination properties of materials.

Additional extensive tests on surface parameters appear to be justified only in relation to underwater (harbor) bursts. However, limited investigations for the purpose of ascertaining the effects of different soil conditions on the decontamination effort are deemed advisable.

CHAPTER 10

DECONTAMINATION OF VEHICLES

Capt. P. H. Ugis, CE, USA

10.1 INTRODUCTION

This is a report on the investigation of vehicle contamination resulting from an atomic bomb detonation at Operation JANGLE, and of the vehicle shielding effects. The test results will be applied to the formulation of field procedures for vehicle decontamination, and they will lead to the standardization of finishes and undercoatings which minimize the contamination hazard and/or facilitate decontamination.

10.2 OBJECTIVES

The field test was conducted:

1. To establish the merits of a series of vehicle rehabilitation procedures and to determine the decontamination techniques which are suitable for troop use and which can be performed with equipment normally available in the field.

2. To determine for each decontamination procedure the team organization and equipment requirements, the associated personnel hazards, and the time requirements for decontaminating various types of vehicles.

3. To determine which parts of vehicles are subject to the most intense contamination, and might present a health hazard either to the vehicle operator or to maintenance personnel.

4. To examine the contamination-decontamination behavior of selected vehicle paints.

5. To determine the shielding afforded by trucks, tanks and personnel carriers required to operate through areas contaminated by fall-out.

10.3 PROCEDURE

10.3.1 Decontamination of Vehicles

The tests were performed at a vehicle decontamination site at the boundary of Rad Safety Red (Monitor required to accompany entering parties) and Green (Monitor not required) areas of Operation JANGLE.

The test equipment used was:

1. An Engineer water pump (p/o No. 4 Engineer Set).

2. A Sellers high pressure jet, used in combination with a steam generator (prototype model).

3. Army Chemical Corps Apparatus, Decontamination, Power Driven, M3A1 (decontamination truck).

4. Vacuum cleaner (commercial model, Rexair).

The decontamination agents tested were:

1. Water, alone.

2. One per cent solutions of Versene and of Tide.

3. Mixtures of steam and each of the above solutions.

The decontaminating procedures tested were:

1. Rinsing and scrubbing of the vehicles with water alone and with each of the detergent solutions.

2. Hosing from the Engineer Water Pump.

3. High pressure hosing from a Sellers high pressure jet with a mixture of steam.

4. High pressure hosing from the decontamination truck.

5. Decontamination of the vehicle cabs with the vacuum cleaner.

Prior to the actual tests a series of dry runs was undertaken to enable personnel to get acquainted with the equipment and its operation.

The types of vehicles processed were:

1. Truck, 1/4 ton, 4 by 4, Command Reconnaisance.

2. Truck, 3/4 ton, 4 by 4, Weapons Carrier.

3. Truck, 2-1/2 ton, 6 by 6, Cargo.

4. Tank, Medium, M-26.

5. Carrier, Cargo, M-29 (Weasel)

A beta-gamma survey meter, Beckman Model MX-5, was used to determine the radiation intensity before and after each decontamination process; areas requiring further processing were thus located.

10.3.2 The Contamination-decontamination Characteristics of Vehicle Paints and Undercoatings

The test arrangements were:

1. Two trucks, 2-1/2 ton, 6 by 6, Chemical Service, were partly covered with selected paints and undercoatings. Locations of painted surfaces are shown in Fig. 10.1. In order to simulate actual field conditions, the surfaces were weathered during trips around the site.

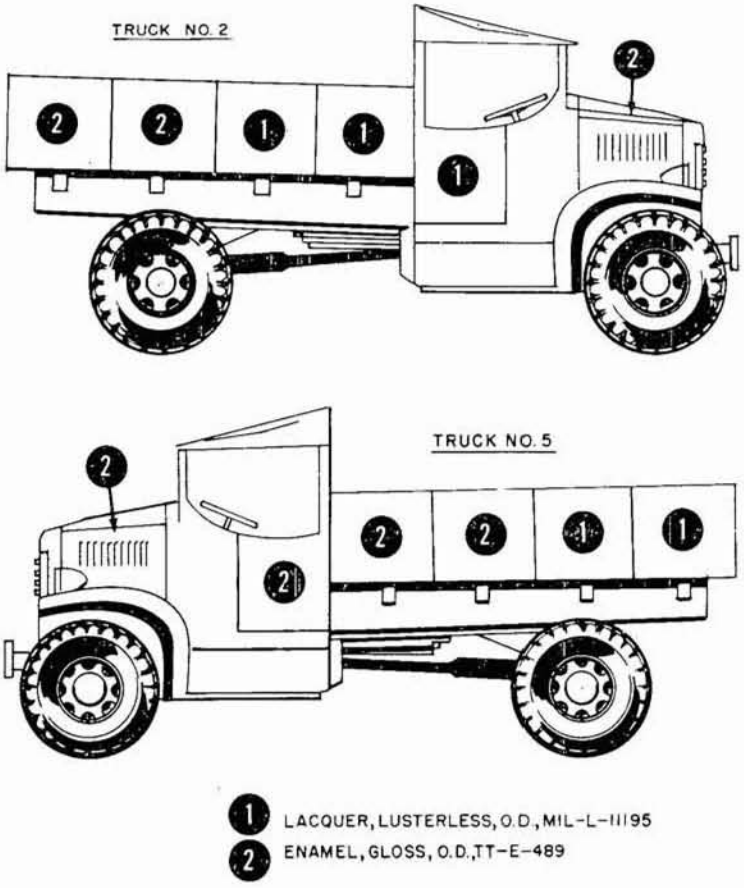

Fig. 10.1 Location of Painted Surfaces on Trucks

2. Two tanks, medium, M-26, were used, both of which were partly covered with applicable painted surfaces (at the site).

The behavior of the paints and undercoats was evaluated by:

1. Driving the vehicles through the contaminated area over various courses and at varying speeds subsequent to the Surface Shot. The routes chosen and the travel times were recorded.

2. Determining the background readings of the instruments before the vehicles were driven into the contaminated area.

3. Measuring the radiation intensity of each vehicle as a whole, and of each painted test surface, with a beta-gamma survey meter, Model MX-5 and a gamma survey meter, Model AN/PDR-T1B at the following times: (a) immediately upon leaving the contaminated area, (b) upon return of the vehicles to the decontamination center, and (c) after a standard decontamination of the vehicular surfaces.

10.3.3 Investigation of Personnel Hazards

Subsequent to the Surface Shot, gamma radiation was determined using survey meter AN/PDR-T1B. Readings were taken in each vehicle cab during its stay in the contaminated area, immediately upon leaving the contaminated area, and upon its return to the decontamination center.

The radiation levels of the cab and engine compartments were obtained prior to and after decontamination by vacuum cleaning.

In addition, a general survey of the vehicles was made with particular attention to "hot" spots.

10.3.4 Special Underground Shot Investigation

In order to determine the effects on vehicles of the Underground Shot, two medium tanks (M-26) were used as stationary targets approximately 2,000 ft from ground zero. This location was chosen to keep the vehicles within the range of the base surge and fall-out without exposing them to serious damage from blast and thermal effects.

The readings taken and the decontamination procedures followed were identical to those prescribed for the post-surface-shot tests.

10.3.5 Measurement of Shielding of Vehicles

Shielding data for radiation from a contaminated area was determined on one medium tank (M-26); a light tank (M-24); a personnel carrier (T18E1); truck, 2-1/2 ton; truck, 3/4 ton; and truck, 1/4 ton. Measurements of the radiation level of the interior and exterior of the vehicles were carried out using the AN/PDR-T1B; and the Beckman Model MX-5, with the window closed. The measurements were made in gamma fields of 100 to 500 mr/hr.

10.4 TEST RESULTS

Prior to decontamination, "hot spots" were detected on vehicles in the following typical locations: on tires, undersides of fenders, back of front bumpers, rear springs, and wherever grease or asphalt spots were present.

Table 10.1 lists the activity levels measured on vehicles contaminated by traveling through the radioactive areas of Operation JANGLE. It is a partial list which illustrates the absence of a vehicle contamination-decontamination problem during Operation JANGLE. All significantly high levels have been included. The data were extracted from the records of the radiological safety operational decontamination station (Atomic Energy Commission) which processed all vehicles contaminated during Operation JANGLE.

1. No vehicle was contaminated to such an extent as to require immediate decontamination during a tactical situation.

2. Vehicle contamination levels were slightly higher after the Underground Shot than they were after the Surface Shot.

3. The beds of vehicles at times showed relatively high levels of activity, arising from contaminated dirt shaken from material retrieved in, and transported from, radioactive areas.

4. Vehicles traveling through areas of similar radiation intensity showed considerable variance in levels of contamination.

TABLE 10.1

Activity Levels on Test Vehicles

Date (days)	Type of Vehicle	Activity (mr/hr) Cab	Wheel	Bed	Maximum Intensity of Area Traversed (mr/hr)
S Day	Truck, 1/4 ton	15	4	15	12,000
	Truck, 2-1/2 ton	2	18	0	40,000
S + 1	Truck, 2-1/2 ton	20	20	1	20,000
	Truck, 1/4 ton	0	15	0	9,000

TABLE 10.1 (Continued)

Activity Levels on Test Vehicles

Date (days)	Type of Vehicle	Activity (mr/hr) Cab	Wheel	Bed	Maximum Intensity of Area Traversed (mr/hr)
S + 2	Truck, 1/4 ton	20	20	--	5,000
	Truck, 2-1/2 ton	2	20	0	160
S + 3	Truck, 3/4 ton	5	0	0	500
	Truck, 2-1/2 ton	5	0	0	150
S + 4	Pickup, 1/2 ton	2	0	0	100
	Pickup, 1/2 ton	2	6	0	400
S + 5 rain, muddy roads	Truck, 1/4 ton	10	20	--	No data
	Truck, 3/4 ton	6	20	--	No data
U Day	Truck, 1/4 ton	20	20	20	No data
	Truck, 3/4 ton	20	20	300	No data
U + 1	Truck, 1/4 ton	10	20	--	No data
	Truck, 3/4 ton	5	1	20	No data
U + 2	Truck, 1/4 ton	20	7	6	10,000
	Truck, 3/4 ton	15	20	20	No data

Table 10.2 lists the levels of contamination-decontamination measured on test vehicles operated in fields of intensity as high as 25 r/hr.

TABLE 10.2

Contamination-decontamination of Test Vehicles

Location	Contamination Levels (mr/hr)						
	Surface Shot in Contaminated Area	Underground Shot					
		First Truck			Second Truck		
		In Contaminated Area	At Decontamination Station	After Decontamination	In Contaminated Area	At Decontamination Station	After Decontamination
Left Front Wheel	5	5	9	5	9	10	3
Under Left Front Fender	6	8	15	9	20+	20+	0.9
Hood	0.3	0.3	0.5	--	--	--	--
Cab	--	--	0.5	--	--	0.5	--

TABLE 10.2 (Continued)

Contamination-decontamination of Test Vehicles

Location	Contamination Levels (mr/hr)						
	Surface Shot	Underground Shot					
		First Truck			Second Truck		
	in Contaminated Area	In Contaminated Area	At Decontamination Station	After Decontamination	In Contaminated Area	At Decontamination Station	After Decontamination
Left Side	1	1	8	0.9	1.1	1	1
Left Rear Wheel	20+	20+	20	4	20+	20+	7
Under Left Rear Fender	6	6	18	1.5	10	11	1.8
Bed	10	10	0.5	0.7	0.8	0.7	1
Right Rear Wheel	18	18	6	1.5	12	22	5
Under Right Rear Fender	7	7	10	1.2	1.8	1.8	3
Right Side	5	--	0.5	0.6	4.2	4.2	0.9
Right Front Wheel	7	5	3	3	3	5	5
Under Right Front Fender	5	18	0.9	0.5	11	10	0.7
Radiator	--	--	4	--	--	3	--
Bumper (Front)	18	--	--	--	20	--	--

Table 10.3 lists the contamination levels of the M-26 tanks as measured 26 hr after the Underground Shot, and the extrapolated values for 1 hr after the Underground Shot. The data were taken after the vehicles had weathered for 26 hr and then had been driven approximately one mile to a decontamination area.

TABLE 10.3

Contamination on M-26 Tanks

Location	Contamination Level (r/hr)			
	H + 26 Hours		H + 1 Hour (Extrapolated)	
	Tank(a) 418-S	Tank(b) 424-S	Tank 418-S	Tank 424-S
Top of Turret	1.7	2.0	42	49
Gunner's Compartment	0.17	0.08	4.2	2.0
Commander's Compartment	0.18	0.08	4.4	2.0

TABLE 10.3 (Continued)

Contamination on M-26 Tanks

Location	Contamination Level (r/hr)			
	H + 26 Hours		H + 1 Hour (Extrapolated)	
	Tank[a] 418-S	Tank[b] 424-S	Tank 418-S	Tank 424-S
Driver's Compartment	0.26	0.12	6.4	3.0
Side of Tank	0.7	1.4-2.5	17	34-61
Front of Fenders	1.4	0.8	34	20
Front Toweye	0.42	0.45	10.2	11.1
Machine Gun	0.29	0.30	7.1	7.4
Right Treads and Bogies	0.08	0.055	2.0	1.3
Left Treads and Bogies	0.08	0.08	2.0	2.0
Engine Compartment	0.49-2.3	0.20	12-59	4.0

(a) Tank 418-S: head-on, engine running, hatches open.

(b) Tank 424: side-on, engine off, hatches closed.

Table 10.4 shows the decrease in contamination level of the M-26 tanks, resulting from weathering and from their removal from the radioactive area (40 to 80 per cent reduction).

TABLE 10.4

Contamination Levels on Tanks Removed from Test Area

Vehicle	Contamination Level (r/hr)	
	Before Removal from Area	After Removal from Area
M-26 Tank (outside)	3.0	2.0
M-26 Tank (inside, open)	1.5	0.17
M-26 Tank (inside, closed)	0.25	0.08

Table 10.5 lists for tank, medium, M-26:

1. The exterior decontamination achieved by hosing with a combination of Versene and Tide in a high pressure water jet at 250 psi delivered by a decontamination truck.

2. The decontamination achieved within the tanks by means of vacuum cleaning.

TABLE 10.5

Decontamination of M-26 Tanks

Location	Activity Level before Decontamination (r/hr)		Activity Level after Decontamination (r/hr)	
	Tank 424-S	Tank 418-S	Tank 424-S	Tank 418-S
Top of Turret	1.5	0.8	0.03	0.005
Gunner's Location	0.08	0.04	Bkgd	0.017
Commander's Location	0.06	0.08	Bkgd	0.014
Driver's Location	0.06	0.12	Bkgd	0.10
Right Exterior	0.8	0.6	Bkgd	0.05
Left Exterior	0.6	0.7	0.02	0.03
Rear Toweye	0.04	0.03	0.02	0.04
Gun Muzzle	0.04	0.08	0.04	0.03
Front of Fender	0.6	0.8	0.03	0.03
Front Toweye	0.2	0.25	0.03	0.03
Machine Gun	0.16	0.16	0.06	0.04
Treads and Bogie Wheels	0.05	0.05	Bkgd	0.03
Engine Compartment	0.13	0.03	0.06	0.02

Table 10.6 lists the contamination-decontamination data on the tanks which were operated through the area to the crater.

TABLE 10.6

Contamination-decontamination Data on Vehicles Operated Near Crater

	M-26 Tank 418-S			M-26 Tank 424-S		
	Contamination Level (mr/hr)			Contamination Level (mr/hr)		
Location	Before Run	After Run	After Decon.	Before Run	After Run	After Decon.
Top of Vehicle		4	1.5	14	14	2.5
Commander		13	9	6.5	6	3
Loader or Compartment		12	9	8	7.5	3
Assistant Driver		20	14	11	10	5
Driver		20	10	11	10	8
Gunner		12	11	6	7.5	4
Outside Left Side		11	3	10	11	4.5
Top Left Fender		12	5	20	16	7
Left Track		6	3	13	15	2.5
Left Bogies		17	6	10	18	5
Left Suspension		20	5	12	16	7
Rear Toweye		--	--	10	8	1.5
Gun Muzzle		12	2	20	14	3
Right Track		10	9	20	8	2
Right Bogies		8	5	9	14	4
Right Suspension		20	6	35	70	7
Outside Right Side		18	5	12	17	5
Top Right Fender		22	8	26	95	10
Front Toweye		—	—	5	4	1
Front of Vehicle		6	4	8	8	2.5
Engine Compartment		20	49	--	—	20

Table 10.7 (with Fig. 10.1) lists the levels of contamination of differently painted surfaces.

TABLE 10.7

Contamination Levels of Differently Painted Surfaces

Truck No. 2[a]		Truck No. 5[a]	
Right Side (mr/hr)	Left Side (mr/hr)	Right Side (mr/hr)	Left Side (mr/hr)
0.7	1.2	1.1	6.0
0.9	1.7	1.7	6.0
1.0	1.2	1.1	3.0
0.5	0.5	0.6	0.5
0.5	0.3	1.2	0.8
0.3	0.3	0.2	0.2

(a) See Fig. 10.1.

Table 10.8 gives the attenuation data for 2-1/2-, 3/4-, and 1/4-ton trucks.

TABLE 10.8

Vehicular Shielding Effects

Vehicle	Field Intensity (mr/hr)	Cab Intensity (mr/hr)	Attenuation	Bed Intensity (mr/hr)	Attenuation
Truck, 2-1/2 ton	35	31	1.66	28	1.25
	140	60	2.33	90	1.55
	300	150	2.00	200	1.50
	2,100	600	3.50	1,000	2.10
Truck, 3/4 ton	80	15	5.33	20	4.00
	28	6	4.66	10	2.80
	16	3	5.33	7	2.29
Truck, 1/4 ton	360	140	2.00		
	1,000	360	2.77		
	1,200	350	3.43		
	1,400	440	3.18		
	1,600	600	2.66		

Table 10.9 lists the results achieved with the various decontamination procedures tested, and shows that the highest degree of decontamination was achieved with high pressure steam.

TABLE 10.9

Results of Various Decontamination Procedures

Type Vehicle	Method of Decontamination	Reading (mr/hr)	Left Front Wheel	Left Side of Vehicle	Right Rear Wheel	Underside of Right Front Fender
Truck, 2-1/2 ton, 6 by 6, Cargo	Chemical Corps decontamination truck and Sellers high pressure jet	Initial	20	1.5	20	17
		Final	10	0.6	17	1.4
Truck, 2-1/2 ton, 6 by 6, Cargo	Chemical Corps decontamination truck	Initial	20	7.0	20	20
		Final	8	0.7	20	6
Truck, 2-1/2 ton, 6 by 6, Cargo	Chemical Corps decontamination truck with Tide solution	Initial	6	7.0	6	7
		Final	1.8	1.5	4	—
Truck, 1/4 ton, 4 by 4, Command Reconnaissance	Low pressure hosing with water	Initial	8	3.0	8	10
		Final	2	1.6	3	3

Table 10.10 gives the attenuation data for the M-24 Tank.

Table 10.11 gives the attenuation data for the M-26 Tank.

Table 10.12 gives the attenuation data for the T18E1 Personnel Carrier.

TABLE 10.10

Attenuation Data for M-24 Tank$^{(a)}$

Location	Field Intensity (mr/hr) External	Field Intensity (mr/hr) Internal	Reduction Factor	Field Intensity (mr/hr) External	Field Intensity (mr/hr) Internal	Reduction Factor
Driver's Seat	310	20	15.5	110	9	12.2
Assistant Driver's Seat	310	20	15.5	110	9	12.2
Commander	310	20	15.5	110	5	22.0
Gunner	310	16	19.0	110	6	18.0
Right Fender	310	120	2.6	110	55	2.0
Left Fender	310	100	3.1	110	50	2.2
Top of Turret	310	300	1.05	110	80	1.4
Outside Driver	310	170	1.8	110	60	1.8
Outside Assistant Driver	310	170	1.8	110	70	1.6

(a) Measurements made on one tank in two different locations at the test site.

TABLE 10.11

Attenuation Data for M-26 Tank$^{(a)}$

Location	Field Intensity (mr/hr) External	Field Intensity (mr/hr) Internal	Reduction Factor	Field Intensity (mr/hr) External	Field Intensity (mr/hr) Internal	Reduction Factor	Field Intensity (mr/hr) External	Field Intensity (mr/hr) Internal	Reduction Factor
Driver's Seat	350	6	58	100	4	25	400	7	57
Assistant Driver's Seat	350	8	44	100	5	20	400	7	57
Commander	350	8	44	100	2	50	400	7	57
Gunner	350	4	88	100	2	50	400	4	100
Assistant Gunner	350	6	58	100	3	33	400	6-7	57-67
Right Fender	350	130	2.7	100	50	2.0	400	220	1.8
Left Fender	350	120	2.9	100	46	2.2	400	220	1.8
Over Motor	350	110	3.2	100	46	2.2	400	--	--
Top of Turret	350	120	2.9	100	60	1.7	400	220	1.8
Outside Driver	350	120	2.9	100	35	2.9	400	--	--
Outside and Assistant Driver	350	60(?)	5.8(?)	100	32	3.1	400	--	--

(a) Measurements made on one tank in three different locations at the test site.

TABLE 10.12

Attenuation Data for T18E1 Personnel Carrier[a]

Location	Field Intensity (mr/hr)		Reduction Factor	Field Intensity (mr/hr)		Reduction Factor	Field Intensity (mr/hr)		Reduction Factor	Field Intensity (mr/hr)		Reduction Factor
	External	Internal		External	Internal		External	Internal		External	Internal	
Driver's Seat	350	20	17.5	100	15	6.7	100	15	7	500	55	9
Commander's Seat	350	18	19.5	100	16	6.2	100	12	8.5	500	55	9
Left Passenger Seat	350	25	14	100	14	7.1	100	11 8 10	9 12.5 10	500	47 48 42	11 10 12
Center Passenger Seat	350	28	12.5	100	12	8.3	100	9 9 10	11 11 10	500	51 41 52	10 12 9.5
Right Passenger	350	26	13.5	100	12	8.3	100	8 8 12	12 12 8	500	33 39 51	15 12 10
Outside Commander's Hatch (12 in.)	350	210	1.7	100	55	1.8	—	—	—	—	—	—
Outside Commander's Hatch (36 in.)	350	240	1.5	100	90	1.1	—	—	—	—	—	—

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[a] Measurements made on one T18E1 in four different locations at the test site.

10.5 DISCUSSION

10.5.1 Vehicle Contamination

Shielded vehicles, tanks, and weasels, which were operated for long periods in the vicinity of the craters produced by both Surface and Underground Shots, were contaminated only slightly. Vehicle contamination did not constitute a hazard to the passengers.

Weasels which operated on the lip of the Surface Shot crater 2 1/2 hr after the Shot were monitored approximately 24 hr after Shot time, and disclosed a level of general contamination of 30 mr/hr. Their treads gave readings of 70 mr/hr, and the levels of activity in the personnel compartments were 10 mr/hr.

Tanks operated in the same areas one day after the Shot displayed activity levels of two or three times background.

In order to achieve maximum surface contamination, the trucks, 2-1/2 ton, 6 by 6, Cargo, selectively painted and undercoated, were operated in the radioactive areas. The trucks were driven through the dust cloud produced by the lead vehicle in field intensities of approximately 25 r/hr with speeds varying from 5 to 20 mph. The readings taken in the cabs of these vehicles after those tests was less than 1 mr/hr.

The evaluation of decontamination techniques on those specially treated vehicles and the determination of the contamination-decontamination characteristics of the test paints and undercoats were discontinued because of the low degree of contamination.

While a thorough decontamination of vehicles appears unnecessary, localized vehicle contamination may constitute a hazard to maintenance personnel. In order to minimize such dangers, monitoring and decontamination of vehicles which have operated in a radioactive area should be added to the normal preventive maintenance procedures.

High levels of intensity were noted in the beds of vehicles used for the transportation of contaminated material from radioactive areas. The highest such bed reading detected during Operation JANGLE was 13 r/hr. The cab reading prior to the decontamination was 140 mr/hr. Vehicles which are continuously engaged in such operations in a contaminated area might thus well become highly radioactive. Their immediate decontamination is therefore indicated.

Essentially, neither the Surface nor the Underground Shots created a tactical vehicular problem. Since no vehicle, after leaving the contaminated area, exposed the operator to a dose rate which might be considered a military hazard, there was no need for the immediate treatment of the vehicles. It should be noted, however, that due to test limitations, vehicles were not operated in areas contaminated to levels higher than 50 r/hr.

During tactical operations, the decontamination of the exterior and interior of vehicles cannot be completely disregarded. A routine decontamination point should be established, where vehicles can be monitored and decontaminated if necessary.

10.5.2 Time Requirements

Strict time relationship could not be established for the various decontamination techniques. The surface characteristics of the vehicles prior to entrance into the contaminated areas, and their respective degrees of cleanliness varied so widely that decontamination time appeared as a function of technique and vehicle part, rather than a function of technique and vehicle type. Furthermore, test vehicles, selectively painted and undercoated for controlled decontamination time studies, did not become sufficiently contaminated after repeated runs through the contaminated areas to permit a time comparison of decontamination techniques.

10.5.3 Limitations of Procedures

All decontamination required substantial quantities of water. High pressure hot water techniques utilizing a steam generator and a Sellers unit require approximately 1,400 gal per hr. High pressure cold water hosing from a decontamination truck requires 1,200 gal per hr while its tank only holds 400 gal. Low pressure hosing from an Engineer pump, standard in field units, is slow and laborious.

10.5.4 Practical Applications

The urgency of the military situation will determine how rapidly and to what extent vehicles must be decontaminated. The thorough and complete decontamination of military vehicles will seldom be necessary. A superficial decontamination should normally suffice to meet the military need and reduce the level of contamination to a point where neither the passengers nor the maintenance personnel will be exposed to any undue hazard. The routine cleaning performed for the removal of dirt can then be applied by troops in the field for the necessary decontamination process.

Soil characteristics are, of course, reflected in the contaminant resulting from a surface or subsurface atomic bomb detonation. It is believed that the dry, fine nature of the soil at the Nevada Test Site lessened the decontamination problem. Moreover, when the vehicles which traveled over contaminated roads were wet by rain after the Surface

Shot, more of them were contaminated. Following the wetting of the roads, the work load of the operational decontamination station increased from an average of 30 vehicles per day to 100 vehicles per day. It must be assumed therefore, that moist soil causes a more serious vehicle decontamination problem. The undersurfaces of vehicles traveling through such moist, contaminated soil might then become more radioactive. On the other hand, the contaminated dust hazard to operators and the upper surface contamination of vehicles would be materially reduced.

Since heavy mud is easily removed from vehicles in cleaning operations, the decontamination of vehicles which are heavily contaminated by moist radioactive dirt should not prove difficult. For example, a Weasel, which carried samples of the crater soil from the Surface Shot, had been exposed on the evening of Shot Day. The next morning, a muddy spot on the sampling device read 50 r/hr. Decontamination to a level of 50 mr/hr was accomplished by scraping the muddy spot with a stick.

Until further study of the effects of soil characteristics on the contamination-decontamination problem has been made, it appears unwise to conclude that the trivial vehicular decontamination problem which existed at the Nevada Test Site typifies the general vehicular decontamination problem which might result from surface or subsurface atomic bomb detonations.

10.5.5 Shielding Data for Vehicles

The shielding afforded by armored vehicles yields the following radiation intensity reduction factors (with respect to gamma radiation) for personnel riding in their normal positions:

Vehicle	Factor
Tank, M-24	16-20
Tank, M-26	45-55
Personnel Carrier, T18E1	10-12
Truck, 2-1/2 ton	2

10.6 CONCLUSIONS AND RECOMMENDATIONS

10.6.1 Equipment

The experimental vehicular decontamination results of Operation JANGLE indicated no need for the addition of specialized decontamination equipment to the present tables of equipment of field units. If vehicle decontamination should be necessary, the decontamination equipment and procedures to be used should be based on the urgency of the situation. The following emergency methods may be used by the vehicle operator:

1. Dry sweeping or brushing of the vehicle, paying particular attention to the removal of as much dirt as possible from the cab.

2. Wiping with wet rags.

3. Brush scrubbing with water or a solution of water and GI soap.

A more thorough decontamination could be accomplished with (1) low pressure hosing and scrubbing, (2) high pressure cold water, and (3) high pressure hot water or steam cleaning.

10.6.2 Man Power and Time Requirements

Man power and time requirements will vary, depending upon the equipment utilized, the urgency of the situation, and the extent of decontamination necessary to eliminate any undue hazard to the operator. The following rule of thumb for time estimates is suggested: it should take no longer to decontaminate to safe levels than it would to remove ordinary dirt from the vehicle.

10.6.3 Chemical Requirements

No addition of chemicals to supply channels for decontamination purposes is deemed necessary. The decontamination which serves the military purpose can be carried out without chemical additives. Just as in ordinary cleaning, a detergent or soap, both of which now exist in supply channels, will expedite the cleaning job.

10.6.4 Personnel Safety

During decontamination operations, the following steps are suggested to minimize the radiation hazard to decontamination personnel:

1. Contact with contaminated parts of vehicles should be avoided wherever possible.

2. Gas masks should be worn until the absence of an airborne hazard is proven.

3. Standard change house procedures should be followed wherever possible. That is, at the completion of decontamination operations, a change of clothes is advisable and washing and showering facilities should be available.

4. No special clothing is necessary for decontamination

operations. Water repellent clothing is desirable for wet operations.

10.6.5 Individual Training

It is recommended that an explanation of the vehicular decontamination problem be part of all atomic energy indoctrination courses. It should include the following facts:

1. Radioactive contamination sticks to vehicle surfaces as does ordinary dirt. For all practical purposes, vehicle decontamination is therefore a cleaning job. The removal of the contaminated dirt eliminates the radiation hazard.

2. The removal of the contaminant from vehicles requires methods normally used for the cleaning of vehicles. Although brushing or sweeping will remove a large percentage of dirt, water is necessary for a thorough cleaning job.

3. Troops should be trained to meet their particular decontamination problem. For instance, if the Chemical Corps decontamination truck is not available, a 3,000-gal water tank and pump might be placed in the bed of a 2-1/2-ton truck, to be dispatched to points where the immediate, thorough decontamination is required. A permanent decontamination station could be set up near a water supply to which point vehicles in need of decontamination might be driven.

4. Although hazards to decontamination personnel appear insignificant, the usual precautions when handling contaminated material should be taken.

5. During travel through a contaminated area, vehicle windows should be closed in order to lessen the dust hazard in the cab.

6. Before reentering a vehicle in a contaminated area, personnel should dust off clothing and shoes as thoroughly as possible in order to reduce the quantity of contaminated dirt carried into the cab.

10.6.6 Shielding

Considerable shielding is afforded in armored vehicles required to operate through radioactively contaminated areas. The integrated dose received by crew members, in general, is less than 1/10th the dose that would be received outside the vehicles. Personnel riding on the fenders of vehicles will receive, roughly, half the dose they would receive if they were afoot.

CHAPTER 11

MEASUREMENTS

R. L. Stetson

11.1 ABSTRACT

Measurements of initial contamination, of the movement of the contaminant during decontamination, and of the residual levels after decontamination were accomplished in two ways: (1) direct measurements were made in the field by detection of beta and/or gamma radiations emanating from surfaces or areas of interest; and (2) indirect measurements were obtained by sampling contaminated surfaces and aerosols, removing the samples from the field and measuring the radioactivity associated with them, and calculating back to determine what the values would have been at the times of interest. These indirect techniques were found to be very useful and necessary for securing laboratory check measurements of field readings as well as for obtaining unique measurements otherwise unavailable. The direct measurements were employed wherever possible using gamma survey instruments and special instruments for detecting beta radiation in a gamma background.

11.2 HISTORY

Prior to Operation JANGLE, measurements of contamination levels and decontamination effectiveness in the field have been performed using beta-gamma and gamma survey instruments. These instruments are designed to detect and measure the primary radiological hazard--the external gamma and beta radiations. It is intended that they provide an average reading of the radiation field at any given location with only general concern as to the source of the radiation.

Previous experimentation has shown that more than just a general knowledge of the location of contaminant and reduction of the field is necessary for accurate assessment of decontamination effectiveness. It is known that the location of contaminant and ease or difficulty of removal can vary widely with the geometrical configuration and the type of material encountered. Furthermore, the amount removed from various locations and materials will vary with the decontamination method employed. The need for an instrument providing directional detection has therefore developed.

Selection of instruments for general radiation-field measurements was based upon the following:

1. Performance in previous atomic tests.

2. Reliability in the ranges of detection anticipated.

3. Availability.

It was felt that the experimentation to be carried on under this project would closely simulate operational procedures. Hence, operational-type survey instruments were chosen.

Prior to this operation, considerable experience in air sampling techniques had been acquired. The simplest and most direct method, that of vacuum sampling through a special filter, was chosen for this field work. Other sampling techniques (involving the removal of contaminant from the field for inspection) were developed as required.

11.3 OBJECTIVES

The objectives of the measurement effort on this project were two-fold:

1. To accomplish direct measurements in the field wherever possible and feasible.

2. To provide indirect measurements where direct measurements were either not possible or not feasible.

11.4 GENERAL MEASUREMENT PROCEDURE

The direct measurements were attempted by use of two types of instruments:

1. Radiac survey meters.

2. Beta counters.

The indirect measurements were sought by use of the following sampling techniques:

1. Air sampling.

2. Soil sampling

3. Surface sampling
   a. Patch sampling.
   b. Adhesive sampling.

4. Waste liquid sampling.

11.5 SPECIFIC PROCEDURE: DIRECT MEASUREMENTS

11.5.1 Radiac Survey Instruments

The instruments used for measuring gamma radiation fields are designated as follows:

Radiac Training Set, AN/PDR-T1B

Radiac Set, AN/PDR-27

Radiac Set, AN/PDR-27c

Radiacmeter, SU-10

Before these instruments were used in the field, their calibration was checked with a radioactive cobalt source. This comparison was performed daily during the tests to insure maintenance of the calibration.

11.5.1.1 Radiac Training Set, AN/PDR-T1B

The AN/PDR-T1B is an ionization chamber instrument used to detect the presence of gamma emitting radioactive materials and to train operators in the use and maintenance of this type of equipment. It is a self-contained portable instrument weighing about 10 lb. It is used for detecting and measuring the intensity of gamma radiation only. The readings on the meter are not cumulative; that is, the meter indicates the amount of radiation (in milli-roentgens per hour) present at any given moment, regardless of the duration of the exposure. The detecting volume (ionization chamber) is located entirely within the steel case of the instrument. All beta and the lower energy gamma radiations are therefore excluded. The equipment has a metal carrying handle and a 1-1/2-in. plastic shoulder strap.

Controls are contained in three knobs and one push-button switch. The zero control adjusts the meter reading to zero. The selector switch turns the set on and off, selects ranges, and changes range scales. Five ranges are provided in milli-roentgens per hour: 0 - 5; 0 - 50; 0 - 500; 0 - 5,000; and 0 - 50,000. The check control manipulates a small beta source enclosed in the case to provide a check of the over-all operation. A meter light switch located in the handle controls the pilot-light illumination of the meter face.

11.5.1.2 Radiac Set, AN/PDR-27 and 27c

These instruments are identical except for certain internal improvements in the later "c" model. They function in a similar manner to the previously described AN/PDR-T1B. However, these instruments are provided with an internally contained Geiger tube and, in addition, an end-window Geiger tube on an extendible cable. This probe detects gamma radiation exclusively when the metal shield is in place over the window and detects beta-gamma when the shield is removed. The detachable probe detects radiation intensities up to 5 mr/hr; the ionization chamber detects gamma radiation above that figure. The meter, weighing about 9 lb, has a metal carrying handle and a plastic shoulder strap. A headset is also provided.

All controls are contained in one knob. The range switch turns the set on and off, changes range settings, and selects range scales. Four ranges are provided in milli-roentgens per hour: 0 - 0.5, and 0 - 5 by means of the detachable probe; and 0 - 50 and 0 - 500 using the internally contained Geiger tube. The meter face can be illuminated by tilting the meter so that the panel is in a 45-deg position.

11.5.1.3 Radiacmeter, SU-10

This instrument is identical in all outward aspects and manipulation to the AN/PDR-T1B.

11.5.1.4 Performance Summary

The Radiac Training Set, AN/PDR-T1B, was generally used in preference to the AN/PDR-27 and 27c. There appear to be two reasons for this choice. First, initial measurements required the higher ranges provided by the AN/PDR-T1B. Once measurements were started with this instrument, there was a natural reluctance to change to another type. This attitude was fostered in part by an early observation of poor correlation between instrument types. Second, the requirement of removing the probe for lower scale readings with an AN/PDR-27, 27c introduced an undesirable variable since the exact location of the detecting volume with respect to the contaminated surface materially affected the readings obtained. This instrument was used only rarely for beta detection due to the limited range[1] available for such measurements.

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[1] With an observed beta-to-gamma ratio of 10 to 1, no beta-gamma measurements could be made in gamma fields higher than 0.5 mr/hr using the AN/PDR-27, 27c; a reading of 0.5 mr/hr with the window closed would give 5 mr/hr when open, the latter figure being the upper limit of detection for the extendible probe.

Although the AN/PDR-T1B and SU-10 were comparatively easy to handle and operate in the field, the following criticisms are pertinent:

1. Although carefully calibrated prior to field use (as indicated previously), poor correlation between instruments was experienced. Differences of as much as 50 per cent were noted.

2. The response was sluggish at temperatures below 50 deg F.

3. In changing range scales, differences of as much as a factor of 2 were observed. For instance, a reading of 40 on the 0 - 50 scale might change to 80 on the 0 - 500 scale.

4. In nonuniform fields, readings divergent by 20 to 50 per cent were observed depending upon the orientation of the instrument in the field.

5. Zero drift appeared to be serious in some cases. Moreover, the provision for zero adjustment as in this instrument presents a psychological problem. In high radiation fields there is a reluctance to take time out to adjust the zero. At the same time the drift is such as to give a feeling of insecurity if frequent recourse to adjustment is not taken; this feeling is heightened by the continuing uncertainty as to whether or not the zero-adjust knob has been accidentally moved since the last adjustment. The zero-adjust knob is located too close to the carrying handle, thereby permitting accidental movement.

Better correlation between instruments of the same type and between types was attained as the operation progressed. This was usually accomplished by selecting, in the field, instruments which were found to agree closely. Listed in Table 11.1 are some examples of coincident readings obtained by specially selected instruments of the types indicated.

11.5.2 Beta Counters

11.5.2.1 USNRDL Beta Counter: Mark V Model I

Five instruments[2] for the detection of beta radiation in the presence of gamma radiation were designed and manufactured at USNRDL. These instruments discriminate against the gamma flux

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[2] For further details see Report USNRDL-344, 20 Feb 1952.

by use of two chambers; both chambers are sensitive to gamma rays, but only one is sensitive to beta particles. The difference in the current from the two chambers is attributed to the beta radiation. These beta sensitive instruments were used to accurately determine the effectiveness of the decontamination methods. Their use made it possible to determine how much contaminant was removed from specific surfaces, without interference from the gamma radiation from surrounding areas. This property also permitted detailed study of contaminant distribution.

TABLE 11.1

Coincident Readings for Three Instruments

Location[(a)]	Readings[(b)] (mr/hr)		
	AN/PDR-T1B	SU-10	AN/PDR-27c
1	240	270	280
2	270	260	300
3	260	250	270
4	260	270	280
5	240	260	280
6	280	270	275
7	220	250	260

(a) Distance between stations equals 50 ft.

(b) Instrument held horizontal at 5 ft above ground.

The five instruments were identical in all respects. Production line techniques were employed in their manufacture so that components and subcomponents could be interchanged. As originally developed, they were designed to operate in gamma fields up to 25 - 30 mr/hr. A proportional, gas-flow principle was employed using an argon-carbon dioxide mixture (65 - 35). The operating voltage ranged from 3,000 to 3,600 v.

Power was supplied by ten to twelve 300-v batteries (Eveready Minimax). The entire power pack consisted of 14 batteries, allowing spares for immediate replacement in the event of failure of one or more units. One battery was connected across a voltage control potentiometer thus permitting fine control of the voltage for calibration purposes. A unique arrangement of jumpers provided a scheme by which batteries could be quickly placed in or taken out of the circuit.

The probe alone weighed between 3 and 4 lb (Fig. 11.1). Two controls were provided--a zero-adjustment and a range-selector switch. Four range positions, from highest to lowest, were designated A, B, C, and D. A gas escape port was provided for allowing a low rate of flow of gas during operation. This port was located in a screw cap which could be removed to permit flushing of the chambers prior to operation of the instrument. Four feet located on the bottom face of the probe permitted minimum contact with the contaminated surfaces while providing for constant positioning of the window at 1/2 in. from the surfaces being examined. The outer dimensions of the probe were approximately 4 by 5 by 6 in. and the window was 3 by 3 in. The effective surface area sensed by the probe was estimated to be 4 by 4 in.

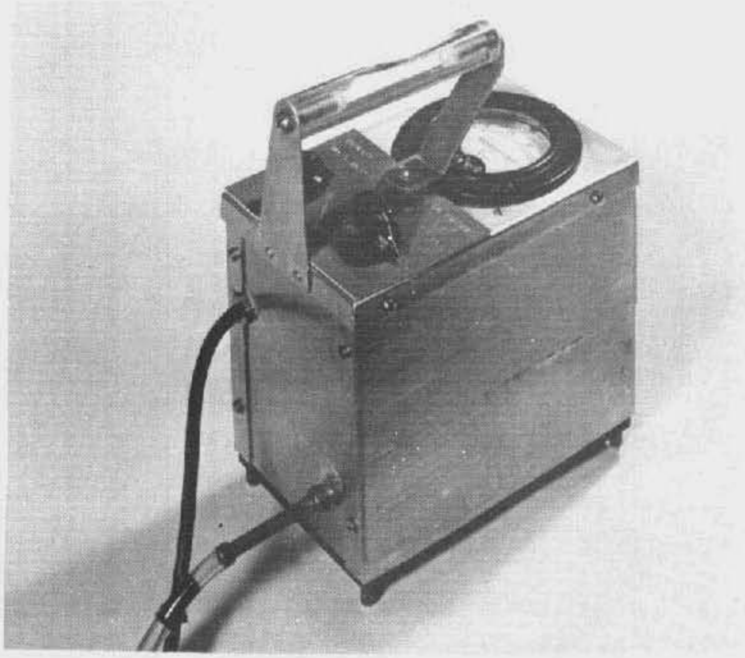

Fig. 11.1 Probe for Beta Counter
USNRDL Mark V, Model I

The entire assembly was mounted on a two-wheeled cart especially designed for travel over rough terrain (Fig. 11.2). Gas was supplied from a cylinder having a capacity of 300 cu in.; this capacity was sufficient to provide for 25 to 50 hr of continuous operation. (No time restriction other than the shelf-life of the batteries was imposed by the power source employed since virtually no current drain occurs during normal operations.) The probe was connected to the power source by 25 ft of cable and to the gas supply by 25 ft of plastic tubing. The tubing and cable were taped together to facilitate handling. The distance of 25 ft was chosen to allow adequate access to the structures and objects being investigated.

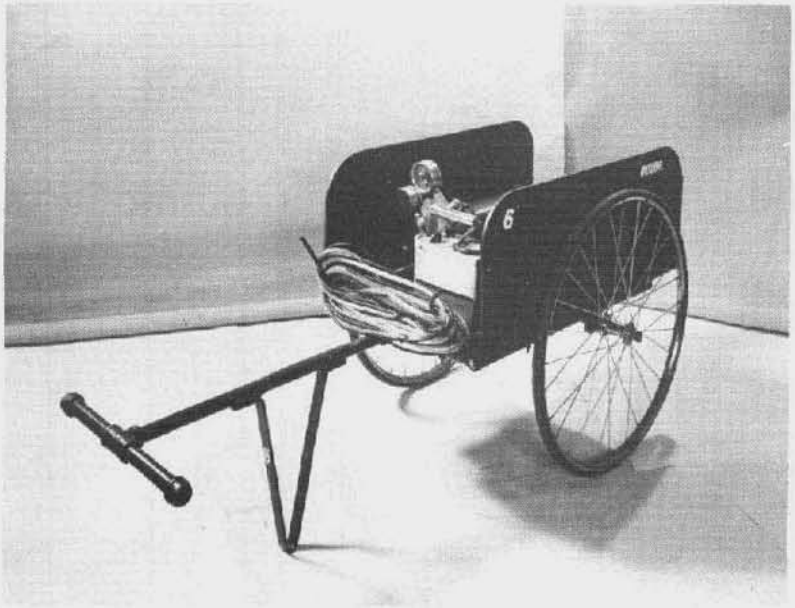

Fig. 11.2 Beta Counter on Cart
USNRDL Mark V, Model I

11.5.2.2 Performance Summary

As indicated previously, design criteria for the USNRDL beta counters were based on anticipated operations in fields of 25-30 mr/hr. Virtually no information was available concerning the amounts of activity to be expected on surfaces at these levels. However, using the best estimates at hand, a range of sensitivity was chosen such that significant readings before and after decontamination could be obtained.

Initial operations in the field divulged the following facts:

1. The range of sensitivity provided was more than adequate.

2. Operations in gamma fields higher than 25-30 mr/hr would be required.

The instruments were therefore modified to permit operation in higher gamma fields. This modification was accomplished by reducing the overall sensitivity and by encasing the probes in 1/8 in. of lead. The results are summarized in Table 11.2.

TABLE 11.2

Operating Characteristics, USNDRL Beta Counter Mark V, Model I

Gamma Field (mr/hr)	Instrument Modification	Sensitivity Range (mμc x k)(a)			
		Range Scale			
		D	C	B	A
0-25	None	0-50	0-500	Not Used	
25-50	Sensitivity reduced by factor of 10	0-500	0-5,000	These scales provided a logarithmic response permitting detection of much higher levels of activity. Ranges shown on left were adequate for the operations.	
50-100	Sensitivity reduced by factor of 10; shielded on 4 vertical sides by 1/8 in. of lead	0-500	0-5,000		
100-150	Sensitivity reduced by factor of 20; shielded on 4 vertical sides by 1/8 in. of lead	0-1,000	0-10,000		

(a) k is an unassigned constant embodying counter geometry, absorption factors and backscatter. Employed here as a convenience, it indicates that the readings obtained are proportional to the activity expressed in curie units.

The modified instruments gave eminently satisfactory performance with due consideration allowed for the fact that they were developmental units of an entirely new type. By maintaining a close check on the calibration and zero adjustment, reliability of the order of 10 per cent was obtained between instruments. Relative accuracy of readings with any one instrument was approximately 3 per cent. However, if the probes were subjected to a higher gamma radiation field than indicated in Table 11.2, saturation of the ion chambers occurred and the instruments became erratic. Either a cutting off of the power source or removal from the field was then necessary to restore normal operation.

All instruments were found to be able to withstand rugged treatment. Accidental dropping of the probes occurred several times. In every case, no malfunction was experienced. In one instance, a probe encased in 7 lb of lead fell from a height of 2 ft to the bed of a truck, bounced over the edge and dropped down another 2 ft where it was supported only by the power cable. It was found to be operating normally when recovered. Although a thin (0.4-mil) aluminum window was used for the beta sensitive chamber, it was adequately protected by a plastic screen.

The large-wheeled carts upon which the instruments were mounted were found to be well balanced and easy to handle over terrain. Transportation to and from the site was accomplished in various types of military vehicles. Often, movement over rough terrain and high speed travel were required. Wheels and axles of two of the carts finally gave way due to the severe jolting and pounding thus experienced. Again, no malfunction occurred in the probes, fittings, or power and gas supply units.

Extremes in weather conditions had little effect on the instruments. They were subjected to some moisture from natural precipitation, both rain and snow, as well as to freezing temperatures. No failures were experienced. Some tendency to temperature dependence was noted but was readily taken care of by rechecking calibration as temperature changes occurred. Some cases of power failure were at first attributed to cold weather conditions. A small battery in the meter circuit required frequent replacement at the time the temperatures were lowest. However, this need for replacement coincided with peak activity in the use of the instruments and it was concluded that the rate of replacement was probably normal.

The surface area covered by the sensitive area of the probe was found to be satisfactory. This was on the order of 4 in. by 4 in. or approximately 100 sq cm.

The physical manipulation characteristics of the instrument were generally good. The weight of the probe as originally designed and manufactured was very close to ideal. However, the addition of the 7 lb of lead shielding made it unwieldy, generally requiring the use of both hands. This requirement was partly due to the fact that the handle provided was not strong enough to withstand the increased weight. The only other serious drawback in manipulation involved the zero-adjust knob. This was of a freely turning type and was often accidentally moved while handling the probe and taking readings.

The trailing power cable and the gas supply line presented no serious problem, either as regards manipulation or contamination. The lead shielding had a tendency to contaminate, the contaminant becoming rather easily imbedded in this soft material.

When readings were taken or when calibration was done, the meter response was very satisfactory on the three upper scales. The needle stabilized within 1 to 3 sec in all cases. The response on the D scale was much slower, requiring from 30 sec to 2 min to reach equilibrium. This slow response made post-decontamination surveys very slow.

11.6 SPECIFIC PROCEDURE: INDIRECT MEASUREMENTS

11.6.1 Air Sampling

The amounts of radioactive materials dispersed in the air by various decontamination operations were examined by air filtration techniques.[3] By sampling the air at a known rate and by subsequently determining the amount of radioactive material retained on the filters, an estimate of the quantity of material per unit volume of air could be made.

Two types of samplers were used:

1. A modified vacuum cleaner, Filter Queen type.

2. A standard Army Chemical Corps Air Sampler, with modifications.

In addition to these methods, filters from face masks and respirators worn by equipment operators were periodically examined for amounts of radioactive materials retained.

11.6.1.1 USNRDL Air Sampler, Modified Filter Queen Type

The Filter Queen vacuum cleaner is a tank-type cleaner which operates on a normal 110-v AC-power supply. It is modified to act as an air sampler by simply attaching a filter holder to the end of the suction hose. Instruments of this type were mounted on the various pieces of decontamination equipment. Power was supplied by portable motor-generator sets also mounted on the equipment. The volume of air passed through the filter could be determined by measuring the average pressure drop across the filter throughout the sampling period, and by using an established relationship between pressure differential and flow rate. An average flow rate of 15-20 cfm could be obtained with this sampling equipment.

Areas downwind from decontamination operations were examined by the use of a further modification of the Filter Queen sampler. The blower unit was removed from the standard housing and encased in a specially designed device for accomplishing sampling in the wind

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[3] A USNRDL report on air sampling technique in the field is in preparation.

stream. This device consisted essentially of a filter holder, diffusion cone, and vertical tail fin. The entire assembly was mounted on an anchored stake 5 ft above ground. A roller bearing swivel permitted a wind vane action so that the sampling cone always faced upwind. Samples were obtained in the same fashion as previously described for the equipment-mounted samplers. Power was supplied by motor generator.

The following types of filter paper were employed singly or in combination depending upon the particular operation under investigation:

1. Chemical Warfare Service, Type No. 5.
2. Chemical Warfare Service, Type No. 6.
3. Hollingsworth and Vose, Type H-70, (Thickness, 0.018 in.).

The filters are listed in order of increasing efficiency.

After collection, the samples were stored and transported in separate envelopes to prevent cross-contamination. The history of each sample was marked on the envelope. Samples were usually counted within 24 hr and values were calculated back to sampling time on the basis of concurrent decay determinations. A gas-filled proportional counter was used to analyze the filter samples. Quantitative determinations were made of both alpha and beta-gamma emitters.

11.6.1.2 Chemical Corps Air Sampler, Modified

Operation of the Chemical Corps sampler is similar to that previously described for the Filter Queen sampler. The power requirement of 24 v, DC, was supplied by two 12-v aviation-type storage batteries. Rates of flow were generally lower than for the Filter Queen sampler with similar filter-paper loadings. Batteries had to be replaced after 8 hr of operation. This instrument was modified to sample in the wind stream in the same manner as the Filter Queen type.

11.6.1.3 Performance Summary

In general, all units gave satisfactory performance under most sampling conditions. Some difficulty was experienced in mounting the heavy motor-generator sets on decontamination equipment. However, the Filter Queen samplers had to be used for those operations in order to obtain sufficient capacity for the higher dust concentrations. The 110-v AC-powered units proved to be more stable under load conditions than the 24-v DC-powered equipment.

Adequate justification was obtained for modification of both types of samplers for wind stream sampling. Comparison of the modified versions with the same samplers as normally used showed that little or no airborne material was picked up by the latter, even though such materials were present in significant quantities.

11.6.2 Soil Sampling

Samples of contaminated soil to a depth of 20 in. were obtained by means of a tubular sampler. A stainless steel tube just large enough to accommodate a cardboard liner 1-1/2 in. in diameter was used. The upper portion consisted of a handle with a movable weight attached for driving the sampler into the soil. The lower end was equipped with a removable monel cutting shoe. The cardboard liner permitted the sample to be removed intact.

Performance of the soil sampler was satisfactory in loose soil but the cardboard liner was disrupted when attempts were made to drive the tube into firm, native soil.

11.6.3 Surface Sampling

11.6.3.1 Patch Sampling

One-foot square patches of the building and paving materials used on the project were mounted on the decontamination test structures and placed near the test-paved areas. Two samples of each were chosen, one to be coated with a plastic spray and removed immediately after contamination; the other was to remain during decontamination operations and be removed later, thus providing a beginning- and end-point for any series of operations. Counting of the samples could then be performed under laboratory conditions thus providing a controlled check of field counting methods.

These objectives were accomplished with the paving materials samples. However, operational difficulties involving movement of the decontamination test structures, coupled with severe weather conditions, largely nullified the efforts with the remainder.

11.6.3.2 Adhesive Sampling

The exposure of adhesive materials—namely Scotch cellophane tape—to the initial contaminating event was accomplished by use of a cardboard mask having four 1-in.-diameter holes. The tape was placed so as to be exposed through the holes and the cardboard frame was secured with masking tape to exterior and interior surfaces of structures. Counting of the samples was performed with the USNRDL beta counter, Mark V Model I.

The sampling of dry contaminant in this manner was found to be very feasible. In many instances, the only information obtained on the nature of the distribution of the original contaminant on, about, and within structures was by means of this technique. To a surprising degree, the samplers were found to withstand moisture and even rain.

11.6.4 Waste Liquid Sampling

A limited amount of waste liquid samples were obtained from building decontamination operations by means of tongs and open-mouthed bottles. The samples were capped and returned to USNRDL for analysis.

11.7 CONCLUSIONS

11.7.1 Survey Instruments

The development of survey instruments apparently has not resulted in a suitable military radiac for use over long periods in a region of serious radiological contamination. While the AN/PDR-T1B was the preferred instrument during these tests, it was far from satisfactory, even though the environment at the test site favored this type of instrument. It is doubtful whether the AN/PDR-T1B would have performed adequately under more typical conditions of humidity, temperature, etc. Maintenance requirements for this, as for all instrument types, are unacceptably high.

11.7.2 USNRDL Beta Counter, Mark V Model I

The need for a directional instrument for assessing decontamination effectiveness was demonstrated in this Operation. The USNRDL beta counter, although a developmental model, performed sufficiently well to provide the required data. In some instances, however, it was necessary to alter the operation plan to allow for the limitations of this instrument.

A military requirement for a directional decontamination instrument has developed as a result of this Operation. Beta detection appears to be a satisfactory method of accomplishing this requirement.

11.8 RECOMMENDATIONS

It is recommended that military and engineering requirements for radiac instruments be subjected to careful examination with the object of providing improved reliability and ease of handling in field situations involving serious residual contamination. Efforts should be made to increase operating life and to reduce maintenance requirements.

It is recommended that development of the USNRDL beta counter, Mark V Model I, be continued. The general physical characteristics of the instrument (minus lead shielding) should be retained or improved, if possible. Satisfactory performance in higher gamma radiation fields is required. Highest fields encountered will be on the order of 1-10 r/hr requiring intermittent operation of the detector. Continuous operation in fields of 300-500 mr/hr can be expected. These figures are based upon a tolerance figure of 3 r total dose per man per operation.

CHAPTER 12

SUMMARY AND DISCUSSION

W. E. Strope

12.1 INTRODUCTION

12.1.1 Purpose

The work done under Project 6.2 was necessarily conducted as a series of independent experiments. This procedure was necessary because the Project was divided among four major military laboratories and because of the varied experimental requirements among the objectives. The purpose of this chapter is to summarize the results of Project 6.2 and to discuss the findings of the individual experiments in relation to one another under the military problem of decontamination.

12.1.2 Scope

Discussion will be limited primarily to the Underground Shot results, since these prove to be the most significant from a military point of view. Major differences for the Surface Burst experimental results will be noted where necessary. The limitations of the data will be clearly expressed and suggestions or recommendations for future work will be proposed. The findings of Project 6.2 will be discussed along the following lines:

A general nature of the contamination situation encountered by the decontamination crews will be discussed briefly with emphasis on the aspects of contamination which were extremely important to subsequent decontamination operations.

A general performance of decontamination measures will be noted, including the general effects of the target characteristics and the field conditions.

The specific decontamination findings will be summarized and controversial data will be discussed. These findings will be then applied briefly to other military situations in an attempt to generalize on the status of decontamination measures as a result of Operation JANGLE.

12.2 NATURE OF CONTAMINATION

12.2.1 Extent of Contamination

A study of the gross distribution of contaminants in Operation JANGLE was not an objective of Project 6.2. However, the extent and intensity of radiological contamination resulting from the Underground Shot had a large bearing on the experimental work conducted and on the nature of the military problem for which this experimental work was performed. The extent of contamination was very much larger than had been predicted prior to Operation JANGLE. As a result, it can be stated that the detonation of a full scale underground weapon would severely contaminate large areas outside the range of physical damage, and as a result many military and industrial installations, otherwise undamaged, may be rendered untenable solely due to an unacceptable radiation hazard. The significance of decontamination studies is therefore greatly increased. Experimentally, the unpredicted extent and intensity of radiation forced many changes in procedure in Project 6.2. In some cases, these changes resulted in some loss of information.

12.2.2 Distribution of Contamination

As expected, the distribution of contamination over experimental structures indicated that the predominant amount of activity was deposited on horizontal surfaces rather than on vertical surfaces. However, in the ratios of activities on surfaces of various orientations, there were large differences reported by the several investigators who gathered information of this type. Table 12.1 summarizes these differences.

TABLE 12.1

Ratio of Horizontal to Vertical Contamination,
Underground Shot

Source	Estimate	Remarks
Werner (Chapter 8)	75 per cent of cases less than 5:1.	Upper value about 10 to 1; lower value 0.8 to 1 (small panels). Smooth surface; no weather.
Dhein (Chapter 7)	300:1 on roof panels to wall panels. 10:1 on panel assembly	Large panels. Variety of surfaces, no weather. Smooth panels, both oiled and clean, no weather.

TABLE 12.1 (Continued)

Ratio of Horizontal to Vertical Contamination,
Underground Shot

Source	Estimate	Remarks
Smith (Chapter 6)	3-10: 1 on painted surfaces. 100-400:1 on roof.	Smooth surfaces after wind and rain. Tar-and-gravel roof; painted or metal walls, after wind and rain.

Dhein, in Chapter 7, reports that following the Underground Shot, roof panels were contaminated more than wall panels by a ratio of about 300 to 1. These data were collected on large panels having a variety of surfaces. In general, the surfaces were appropriate to roofs and walls so that roof areas were generally much rougher and more porous than wall panels. In addition, Dhein presents data on contamination of a fan assembly of panels having orientations varying from vertical to horizontal. These panels were smooth plywood. The data indicate a ratio of about 10 to 1 between the vertical and horizontal fan panels. All these data were collected on the first and second day after burst so that weathering was of minor consequence.

Werner, in Chapter 8, presents a great deal of data on very small smooth-surface panels which had been protected from all the weathering. The data show that in 75 per cent of the cases, the ratio between vertical and horizontal surfaces was less than 5 to 1. Maximum ratio found was of the order of 10 to 1. These data agree with the smooth fan panels exposed by Dhein.

Smith does not report distribution data in Chapter 6 because of the small number of measurements, and because of the fact that measurements were taken 6 days after burst after serious weathering by wind and rain. However, a survey of the levels found on the experimental buildings indicated a horizontal-to-vertical ratio ranging from 3 to 1 to 10 to 1 on smooth surfaces. This agrees with the Werner data and the fan assembly data of Dhein. In addition, data in Chapter 6 on tar-and-gravel roofs vs painted walls show a ratio of the order of 100-400 to 1 which agrees, roughly, with the 300 to 1 quoted by Dhein. Apparently, the ratio of horizontal to vertical contamination may vary between 5 to 1 and 300 to 1 depending on the situation. An important factor, apparently, is the gross difference in surface characteristics between usual roof materials and usual wall materials. Since a knowledge of distribution, especially between vertical and horizontal surfaces, is essential to a determination of the usefulness of decontamination, it is apparent that additional work is urgently needed to clarify this situation.

Data on surfaces sloped between horizontal and vertical indicate that the amount of contamination varies evenly between these values. Little data were obtained on the contamination of the interior of structures through broken windows, etc. Smith, in Chapter 6, states that little contamination was observed on interior wall surfaces. No information is available in Chapter 6 on contamination of interior floors and other horizontal surfaces. Some observations by Werner, in Chapter 8, provide clues to contamination of interior floors. Data on contamination on horizontal surfaces protected by an insloping or overhanging surface indicate that these surfaces were contaminated less than exterior horizontal surfaces by a factor of between 2 and 10. Unless data of this type are obtained in future projects, this minimal information will present a serious problem in evaluating and planning decontamination operations.

12.2.3 Tenacity of Contamination

In general, the contamination resulting from the Underground Shot was of small particle size and was consequently quite tenacious. In regions of very heavy contamination, the upper layers were readily removed. Nevertheless, in most instances, the tenacity of the contamination was of the same order of magnitude of that experienced in underwater bursts so that decontamination performances were not startlingly different. As in the case of the relative levels of contamination intensity, the effect of gross differences in surface materials was clearly evident. Generally, smooth and nonporous surfaces were very superior to other materials, the contamination being very difficult to remove from very rough and porous surfaces such as tar-and-gravel roofs, etc. However, with minor differences in surfaces--i.e., with surface coatings and even with relatively smooth materials such as bare metal and bare wood--no appreciable tenacity differences were observed.

12.2.4 Effects of Weather on Contamination

After the Underground Shot, high winds persisted for several days. Six days after burst a light rain occurred. Only qualitative data were reported on the effects of this weathering on contamination characteristics. It is definite that the wind and rain partially decontaminated the experimental buildings. In some cases, decontamination by weather of the order of 90 per cent may have occurred. It is also probable that the tenacity of the residual contamination was significantly increased by the rain.

Perhaps the most spectacular effect of the weather on contamination was the movement of large amounts of activity by the high winds. This process generally consisted of moving contamination near the crater area to areas further downwind. On the second day, because of this process of recontamination, intensity levels at about a mile downwind were actually increased despite decay. It is certain that the movement of contamination from an underground burst by winds will be a serious problem if decontamination operations are considered during the first few days after the detonation.

It was also noted that the rain did not move the contamination significantly. Very little penetration of contaminant into the ground was observed. The rain did inhibit the movement of contamination by the wind.

12.3 GENERAL DECONTAMINATION PERFORMANCE

12.3.1 Measurement of Decontamination Performance

The effectiveness of decontamination measures is reported in Project 6.2 in terms of the percentage of initial amount of contamination remaining after the decontamination measure is accomplished. This is in agreement with the practice in the literature of measuring decontamination performance as a fractional part of the initial level. However, there were numerous indications in Project 6.2 that this method of measuring decontamination performance was unsatisfactory. It was shown in several experiments that the effectiveness of decontamination varied with the absolute initial level. In general, the effectiveness increased with increasing levels of contamination. Consequently, in many cases, the performance was very difficult to determine because of gross differences in initial level. Furthermore, a great deal of study will be required in order to reach a meaningful evaluation of the various experiments in this Project. There were some indications that decontamination measures tended to reduce the contamination to an absolute level regardless of initial level. However, these data were not conclusive. Before the performance figures quoted in the various parts of this Project report are used for predicting the performance of decontamination measures in the field, it will be necessary to conduct a careful evaluation of the data, and it is also probable that it will be necessary to clarify the situation with regard to the proper measurement of decontamination performance. At the present time, the quantitative values reported in Project 6.2 should be treated with a great deal of reserve.

12.3.2 Performance of Materials

A large number of common building materials and surface coatings were tested in various experiments. The significant fact resulting from these tests was that only gross changes in surface characteristics resulted in observable changes in decontamination effectiveness. In general, smooth, hard, nonporous surfaces seem desirable. It was easy to observe differences in the performances of such widely different surfaces as paint, bare wood, and tar and gravel, but it was difficult to detect differences between various surface coatings applied to identical materials and, in some cases, between the performances of different materials whose surface characteristics were not grossly different. It is important to observe that the effects of changes in gross surface characteristic were not nearly as great as the effects of orientation of the surface. In no case did the differences observed reach the order of magnitude of the differences between horizontal and vertical surfaces. In many cases, no difference in decontamination performance was observed, even between grossly different surfaces, when the performance was expressed in terms of a fractional part of the initial activity remaining. In this regard, the surface characteristics of materials were far more important to the determination of initial level than to the decontamination performance. On tar-and-gravel roofs for instance, a hot-liquid hosing method was as effective as on painted metal surfaces, but because the tar-and-gravel roofs contaminated to a very much higher level, the final levels were, in many cases, higher than the initial levels on the painted metal.

In summary, it appears from the experiments performed under Project 6.2 that gross differences in surface characteristics of materials are important in determining the level of contamination but there is no conclusive evidence that <u>materials</u> have an important effect on decontamination performance.

12.3.3 Effect of Shape and Construction Details of Structures

The effect of orientation, and particularly of horizontal and vertical orientation, on initial levels of contamination has already been discussed. There appears to be no conclusive evidence that orientation significantly affected decontamination performance. There is evidence on the experimental buildings that even minor irregularities of surface, as represented by the corrugations in the metal structures, had a marked effect on decontamination performance. The performance of hosing methods was reduced by approximately a factor of 2 over the performance on flat surfaces. Corners, joints, and roof parapets also made difficult decontamination situations. In summary, there was clear evidence that irregular surfaces, joints and similar construction features had more effect on decontamination performance than all but the most extreme degree of surface roughness and porosity.

12.3.4 Effect of Field Conditions on Decontamination Measures

The field conditions under which these experiments were conducted were far from optimum. Most of the field decontamination work was done following the Underground Shot, during a period of high winds and freezing weather. The effectiveness of the decontamination personnel was seriously reduced. The cold weather put the liquid decontamination measures to a severe disadvantage and the effectiveness figures quoted should be regarded as a lower limit of the field effectiveness to be expected under normal conditions. The lack of optimum operating conditions had a strong effect on decontamination effectiveness in other ways. The availability of water was limited so that short cuts in the liquid decontamination measures had to be taken. Optimum pressure characteristics were not achieved with the equipment available. These factors should be considered in evaluating the results of Project 6.2.

12.4 SPECIFIC DECONTAMINATION PERFORMANCE

12.4.1 Open Land Areas

Earl, in Chapter 2, reports the result of experiments in removing or burying contamination on open land areas. Reitmann, in Chapter 3, reports experiments designed to recover the use of land areas by erecting a barrier of earth at the periphery of the useful area. Earl found that by using earth-moving equipment and plows, it was possible to reduce the radiation intensities over fairly large areas by a factor of 4 to 10 and that the effort required to do so was reasonable. Reitmann found that a 4-1/2-ft earth barrier would reduce the radiation intensity within the barrier by a factor of about 4. It appears that the clearing technique is more efficient than the barrier technique for general use. However, for certain uses, such as the reduction of intensities on streets or where buildings and other obstructions prevent the clearing of a large area, the barrier technique may be useful.

12.4.2 Paved Areas

Most of the experimental work on paved areas was performed on the existing asphalt road system, which was in poor condition. Heiskell, in Chapter 4, was principally concerned with surface removal methods--applying flame to soften the surface and following the flame treatment by scraping. This method, which is that used in commercially available road planers, was extremely effective, reducing the contamination on the asphalt road by approximately a factor of 30.

Maloney, in Chapter 5, conducted an extensive series of tests involving methods which did not remove the surface, such as vacuuming, sweeping, hosing, etc. His methods performed generally in the region of a decontamination factor of 3 to 5 with high pressure water hosing being the best. Both Heiskell and Maloney performed independent experiments using a fiber brush on asphalt roadways. Their results agree roughly on a decontamination factor of 3 to 4. The essential finding of these experiments is that the road planing method must be developed if decontamination factors of the order of 10 or better are desired. Only Heiskell reported work on the decontamination of concrete. The concrete strip available had a very poor surface which resulted in glazing of the surface by the burner flame. As a result, decontamination factors of 2 to 7 were reported, but this probably represents the lower limit of effectiveness with the flame cleaning method.

In summary, surface removal methods involving the burner flame were far more effective than other methods, especially on asphalt roads. And, since commercially available road planers utilizing this method are as fast as, or faster than, the competitive methods, the flame cleaning technique warrants development.

12.4.3 Buildings and Building Materials

Information on the effectiveness of various decontamination techniques on buildings and building materials was gathered by several investigators and reported in Chapters 6, 7, 8, and 9. There is a wide divergence in the results in the various investigations. For instance, Smith, in Chapter 6, recommends vacuum cleaning as an effective method, while both Dhein, in Chapter 7, and Smith, in Chapter 9, conclude that vacuum cleaning is relatively ineffective on building materials. Other observations vary in a similar manner. It will take a considerable evaluative effort to reconcile the differences in the various chapters of this report. An evaluation of the data has been started at USNRDL and will be reported at a later date. At present, it is possible to summarize the data only very generally. It appears that the capability of the tested decontamination methods with respect to the Underground Shot was such as to reduce the level of contamination by a factor of approximately 2 to 10. There is some evidence that higher factors of decontamination are possible. More detailed results will have to await a reconciliation of the data. The Project Officer considers that it is impossible, at this time, to recommend specific decontamination methods on the basis of the information of this report.

12.4.4 Vehicles

Contamination of vehicles was not serious at Operation JANGLE and it is apparent that vehicle decontamination is not a major military problem. Such decontamination as is necessary can be easily accomplished, and adequate data are presented in this report to provide a basis for a standing operating procedure.

12.4.5 Application to Military Situations

Operation JANGLE emphasized the radiological significance of the underground weapon. If the results of the operation are extrapolated to a tactical weapon yield, it appears that a large area of 5 to 20 square miles will be contaminated to such an extent that installations within this region will be unusable solely because of an unacceptable radiation hazard. This area is very much larger than the area of severe physical damage for an air burst weapon. Before routine operations can be resumed, delays of a few weeks to over a year will occur unless countermeasures are undertaken.

The countermeasures information obtained by Project 6.2 indicates that the best present methods and equipment have a capability of reducing the intensity of radiation fields by a factor of 5 to 10 within a land target complex. The methods which accomplish this reduction are reasonably fast and utilize standard equipment. It is probably practicable to reclaim a military installation using these methods during a period of perhaps one week, utilizing manpower and equipment available to the installation. Whether a reduction factor of the order of 5 to 10 is sufficient to make decontamination a useful military countermeasure is being investigated in a separate study at USNRDL.

An evaluation of the effects of high residual contamination on military operations and installations should be undertaken, and the required effectiveness of countermeasures should be determined more fully than at present. The data derived from Project 6.2 must be regarded as exploratory in nature. More definitive results should be the aim of future experiments.

12.5 RECOMMENDATIONS FOR FUTURE WORK

12.5.1 Decontamination Methods

It is recommended that future experimental work be directed toward gaining a thorough knowledge of the capabilities of a limited number of decontamination techniques selected as the most useful in the military situation on the basis of present data. Previous experimental work has suffered from the use of diverse methods and pieces of equipment. Consequently, only a vague and often qualitative knowledge of the capabilities of decontamination methods is available.

12.5.2 Materials

It is recommended that work on surface materials be deemphasized so that minor differences in surface characteristics are ignored. Increased emphasis should be placed on conducting future field tests on realistic segments of a land target complex. The principal investigators in Project 6.2 have made various suggestions for accomplishing this. It is believed that future work should be done on full scale segments of land target complex including buildings, paved areas, land areas, and normal drainage channels.

12.5.3 Target Location

It is recommended that future field work be directed toward determining decontamination performance over a range of contaminating situations varying from that resulting at the periphery of the contaminated area to that resulting in the most contaminated region in which reclaimable structures can be anticipated. For this purpose, a number of full scale target segments should be located at various distances from the point of detonation so that all decontamination methods can be tested under like situations. In Operation JANGLE, some methods were tested in the peripheral regions, while others were tested in the region of heavy contamination. It is doubtful whether the information gathered under these differing situations can be correlated.

12.5.4 Integration of Decontamination Methods

It is recommended that future field tests of decontamination methods be conducted in a highly coordinated fashion rather than as individual experiments in different regions and involving different materials of the land target. An operating procedure should be set up for the decontamination of the complete target segment visualized for future tests, and effectiveness and man power measurements should be made for these segments as a whole as well as for the individual methods on the particular surfaces to which they apply.

12.5.5 Decontamination Instrumentation

It is recommended that other measurement techniques be developed for the conduct of future field test of decontamination methods. In particular, an instrument which will satisfactorily measure the amount of contamination on a surface before and after decontamination is essential. This instrument must be capable of operating satisfactorily in general gamma fields up to several r/hr. It should be also recognized that a military requirement exists for such an instrument. Without it, it cannot be determined whether a decontamination method is performing properly until the entire area has been decontaminated, so that the general gamma radiation intensity is reduced. It appears to be important to be able to assess the ultimate result of a decontamination operation in the very early stages in order to avoid needless waste of effort and man power in a hazardous operation.

12.5.6 Radiological Safety

It is recommended that the radiological safety requirments incident to reclaiming a contaminated area be integrated into the study of decontamination methods at future field tests. Present techniques for assessing the radiological situation and for assuring safe operations appear to be entirely inadequate for use in military operations.

Experimental studies in the field of radiological safety must be accomplished in connection with all full scale decontamination operations in the future if progress is to be made in this field.

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